REPRODUCTIVE CYCLE AND SEX REVERSAL OF *PAGELLUS ERYTHRINUS* (LINNAEUS, 1758) IN THE GULF OF TUNIS (CENTRAL MEDITERRANEAN)

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ملخص

موسم التكاثر وتغير الجنس عند سمك المرجان *Pagellus erythrinus* في خليج تونس: لدراسة تكاثر سمك المرجان الأحمر *Pagellus erythrinus* بخليج تونس، تم جمع 807 سمكة خلال الفترة الممتدة من فيفري 2003 إلى جانفي 2004 من خلال عمليات الصيد بالجر القاعي. تتراوح الأطوال الجملية بين 7,6 و 28,5 صم. تميز هذا النوع ب hermaphrodisme protérogyne. قدر عامل إناث/ ذكور ب 2,78. ويتغير الجنس بين 17 و 18 صم. يمتد موسم التكاثر من شهر أفريل إلى أكتوبر وأساسا من ماي إلى جويلية. وارتبط ذلك بارتفاع درجة حرارة مياه سطح البحر من 16 إلى 24 درجة. قدر الطول عند أول نضج جنسي ب 14,6 صم بالنسبة للإناث و 15,8 صم بالنسبة للذكور.

كلمات مفاتيح: المرجان الأحمر، التكاثر، النضج الجنسي، تغير الجنس، خليج تونس.

RESUME

Cycle de reproduction et inversion du sexe chez *Pagellus erythrinus* dans le golfe de Tunis : Dans ce travail, nous étudions le cycle sexuel et l'inversion sexuelle du pageot commun *Pagellus erythrinus* dans le golfe de Tunis. De février 2003 à janvier 2004, un total de 807 individus ont été échantillonnés mensuellement à partir des opérations de chalutage benthique. La longueur totale varie de 7,6 à 28,5 cm. L'espèce a été caractérisée par un hermaphrodisme protérogyne. Le sex-ratio (femelles / mâles) a été de 2,78. La saison de ponte s'étend d'avril à octobre et principalement de mai à juillet. Cette dernière est liée à l'élévation de la température des eaux de surface qui passe de 16 à 24°C. La première maturité sexuelle (L_{50}) se situe chez les femelles à une longueur totale de 14,6 cm et chez les mâles à 15,8 cm. L'inversion du sexe a pris place à des longueurs comprises entre 17 et 18 cm.

Mots clés: *Pagellus erythrinus*, reproduction, première maturité sexuelle, inversion de sexe, Golfe de Tunis.

ABSTRACT

The reproductive biology of the common pandora *Pagellus erythrinus* was investigated in the Gulf of Tunis. A total of 807 specimens were collected by bottom trawl on a monthly basis between February 2003 and January 2004. Total length ranged from 7.6 to 28.5 cm. The species was characterized by protogynous hermaphroditism. The overall females-to-males sex-ratio was 2.78. The reproductive season extended from April to October and mainly from May to July as the SST ranged between 16 to 24°C. First maturity (L_{50}) was reached at 14.6 cm total length for females and 15.8 cm for males. The sex reversal took place between 17 and 18 cm.

Keywords: *Pagellus erythrinus*, reproduction, first maturity, sex reversal, Gulf of Tunis.

INTRODUCTION

The common pandora *Pagellus erythrinus* (Linnaeus, 1758) is a demersal fish common in the Mediterranean and Black Sea and extends from Angola to Norway in depths from inshore waters above various bottoms (rocks, gravel, sand and mud), down to 320 m (Fisher *et al.*, 1987; Mytilinéou, 1989). It's most common at depths from 20 to 100 m, with young individuals found near the coast. The species exhibits hermaphroditism (Buxton & Garratt, 1990; Ghorbel, 1996; Pajuelo & Lorenzo, 1998). In the Mediterranean, it is a spring-summer spawner (Girardin, 1981; Mytilinéou, 1989; Ghorbel, 1996).

In Tunisian waters *P. erythrinus* among Sparidae fish species constitute an important fishery resource. It is one of the most abundant species in the benthic fishery landings. Indeed, it represents from 8 to 15% of the catch by benthic trawling in the Gulf of Gabès (Ghorbel *et al.*, 1997) and 11% in the Gulf of Tunis (Zarrad *et al.*, 2000).

A previous biological study on common pandora was carried out in the Gulf of Gabès by Ghorbel (1996) and Ghorbel *et al.*, (1996) but no reproductive information on the Gulf of Tunis has been published. The present paper fills the gap with information on sex-ratio evolution, period of spawning, length at first sexual maturity and length at sex reversal. These characteristics are necessary for the stock assessment and the sustainable management of the fisheries. This work was based on the program of management of benthic trawling in the Gulf of Tunis, under the framework of the Project ESREB (Evaluation des Stocks des Ressources et des Ecosystémes Benthiques).

MATERIALS AND METHODS

Our study area is the Gulf of Tunis that is located in the central Mediterranean. In the Northeast, there is the Sardainia Channel, and towards the Northwest the Sicilian Strait. The area is about 2000 km^2, the coastline is approximately 160 km, and the maximum depth is about 130 m (Figure 1). This Gulf is an area with an important fishery activity involving different fishing gears and target species, related to the seasonal variation in species abundances.

A total of 807 Common pandora were obtained from monthly benthic trawling surveys (12 surveys, one a month) conducted in the Gulf of Tunis from February 2003 to January 2004, by cooperation with fishermen. During each survey we measured the sea surface temperature (SST) by a WTW probe.

For each individual, we measured the total length (TL, 0.1 cm), total weight (TW, 0.01 g), eviscerate fish weight (EW, 0.01 g) and gonad weight (Wg, 0.01g). Sex and sexual maturity stages were determined macroscopically. Five macroscopic stages of maturity for both sexes were classified as follows: stage I, immature; stage II, resting; stage III, repeining; stage IV, ripe; stage V, spent (Table I). Sex-ratio (females: males) was calculated monthly and for total:

$$\text{Sex-ratio} = F/M,$$

where F = number of females and M = number of males. For the class sizes, the sex-ratio was calculated as percentages of unidentified, hermaphrodites, females and males. The significant differences from the expected ratio (1:1) were tested by a χ^2 test (Sokal & Rohlf, 1987).

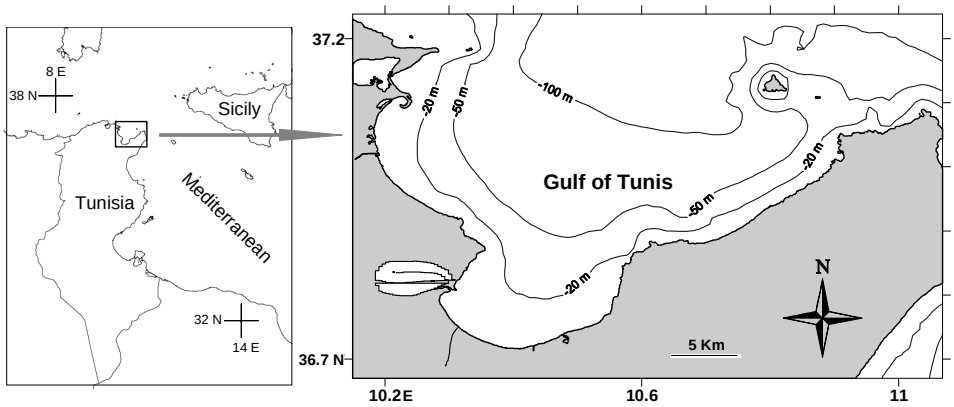

Figure 1: Location of the study area.

Table I: Macroscopic sexual maturity stages of *Pagellus erythrinus.*

Stage	Females	Males
I : Immature	Very thin filaments, such can be seen only in specimens that have not reached their first maturity.	
II: Resting	Ovaries are rose, rounded, very small and translucent.	Testes are grey, flattened, very small and translucent.
III: Repeining	Developing ovaries are swollen with orange eggs visible to the naked eye. They occupied 50-75% of the abdominal cavity.	Testes show some thickening. They are white and occupied 50-75% of the abdominal cavity.
IV: Ripe	Ovaries are very large occupied the entire abdominal cavity. Eggs are orange and run from vent on slight pressure.	Sperm run from vent on slight pressure. Testes are white, very large and occupied the entire abdominal cavity.
V: Spent	Ovaries are flaccid, bloodshot and small in size ovary dark red.	Testes are flaccid and smaller in size. The colour is grey-white.

The sex reversal length was estimated by the method of Shapiro (1984). It consists of the representation of the two size frequencies distributions (1 cm for each class) for both sexes in the same graphic. For protogynous species females occupy small size ranges, males occupy large size ranges, with a zone of overlap. For each class size of the overlap zone, the number of females and males are added to plot a new size frequency distribution. The sex reversal length is the median of the resulting distribution.

The frequency distribution of the maturity stages and the variations in GSI were used to determine the spawning period. The GSI was calculated by the following expression:

$$GSI = 100\ Wg/EW$$

where Wg = the gonad weight and EW = eviscerate weight. This index was calculated as monthly mean.

Length at first maturity, the size at which 50% of individuals reach sexual maturity was estimated separately for females (n = 164) and males (n = 114) in the peak of common pandora spawning period, to avoid a misclassification between regressed and immature fish. It was computed from the proportion of mature individuals (stages III, IV and V) for each 1 cm size class. L_{50} was estimated by means of the analytical method based on a logistic regression model (King, 1995; Gorbel *et al.*, 1996):

$$P(L) = 1/(1+e^{-r\,(L - L_{50})})$$

where P(L) = the proportion of mature individuals in each length class, L the mean length of the total length class, r the slope, and L_{50} the size for 50% of mature. Length at full maturity (size for 95% of individuals are mature: L_{95}) was also estimated for both sexes. Multivariate analysis Hotelling's T^2 test (r and L_{50} are tested simultaneously) was used to compare the logistic model between females and males (Bernard 1981).

RESULTS

Population structure and sex-ratio

In total 807 specimens were sampled during the study. Fish sizes were ranged from 7.6 to 28.5 cm (Figure 2). The samples were composed of 490 females, 176 males, 65 hermaphrodites and 76 undetermined, giving a global sex-ratio of 2.78 that significantly deviates from the hypothetical distribution of 1:1 (observed χ^2_{obs} = 74.02 > theoretical χ^2 = 3.84). We note that the hermaphrodite fish was with dominance of male character. Indeed, individuals were with well-formed testes and residues of degenerated ovaries.

In the mean spawning period (May to August) the sex-ratio was under 2 with a lowest value in August (1.58) (Figure 3). However, it was higher than 2 in the other months with a maximum of 4.22 in December.

According to protogynous hermaphroditism, the sex-ratio (F/M) of the species decreases with the size class (Figure 4). Indeed, for the size classes 14 and 15 cm the sex-ratio was higher than 5, after it decreases to be under 1 for the class size 19 cm. We didn't catch any female with a size bigger than 25 cm.

Length at first maturity

Fifty percent mature (L_{50}) occurred at 14.6 (±0.26 SE) cm and 15.8 (±0.15 SE) cm for females and males, respectively (Figure 7). Length at full maturity (L_{95}) was 16.6 cm for females, and 18.1 cm for males (Table II).

A significant difference in sexual maturity evolution (r and L_{50} were tested simultaneously) was found between males and females of *Pagellus erythrinus* (Hottelling's T^2 test $T^2_{observed}$ = 31.4 > $T^2_{0.05;2,23}$ = 7.2). So we could confirm that there was a difference in L_{50} ($F_{observed}$ = 20.1 > $F_{0.05;\,2,23}$ = 4.35) for both sex.

Length at sex reversal

Sexual reversal took place between 17 and 18 cm. Indeed, following the method of Shapiro (1984), 17 cm is the median distribution of 658 individuals ranging in overlap size, of both sexes, from 14 to 24 cm.

Sexual cycle

The monthly frequencies (percentages) of the different gonad stages are represented in the figure 5. Ripe stages were present from April to October, with the highest importance from May to August. In September, most common pandora have already finished spawning and began the sexual resting period except some individuals that still could spawn in October. In the spawning period the monthly proportions of ripe females were upper than 50% (until 86%) but for males were lower than 38%.

The evolution of the mean GSI for females and males showed similar patterns (Figure 6). The mean values of GSI gradually increased from March to May when reaching the highest values 4.17 and 2.09 for females and males, respectively. Then, the GSI decreased to lower values in September. Indeed, the main reproduction season was, with GSI peaks, from May to July. The sexual resting period took place from November to February (GSI under 0.7 for females and 0.5 for males).

We conclude from the analysis of macroscopic stages of sexual maturity and the monthly mean GSI evolution, that the reproductive season of *Pagellus erythrinus* extended from April to October, with a peak in spawning activity in May-July as the sea surface temperature (SST) ranged between 16.4 to 24.1°C.

DISCUSSION

Pagellus erythrinus displays protogynous hermaphroditism. Indeed, there are individuals with well-formed testes and residues of degenerated ovaries, Females dominate in smaller sizes and males in larger sizes. This character has already been observed for the species in the Mediterranean (Papaconstantinou *et al.*, 1988; Mytilinéou, 1989; Ghorbel, 1996) and in the Atlantic (Pajuelo & Lorenzo, 1998).

The sex-ratio in the Gulf of Tunis was in favour of females (2.78:1 or 73%) as in other areas: both in the Gulf of Gabès (Ghorbel, 1996) and in Libyan waters

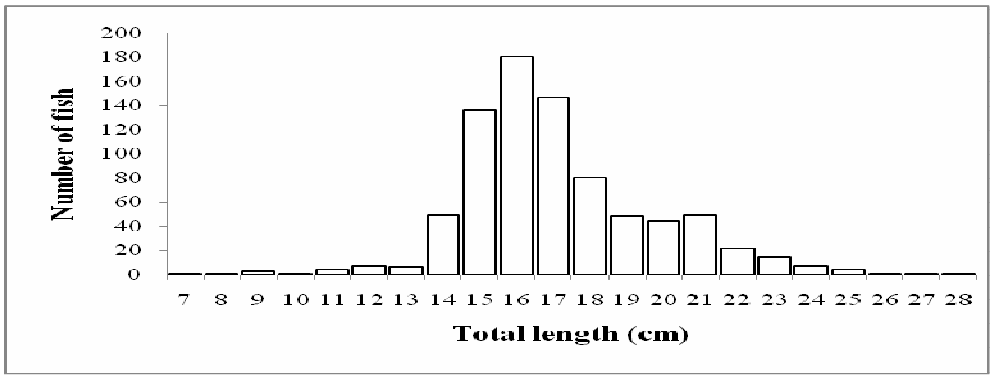

Figure 2: Length frequencies of sampled fishes of *Pagellus erythrinus* in the Gulf of Tunis.

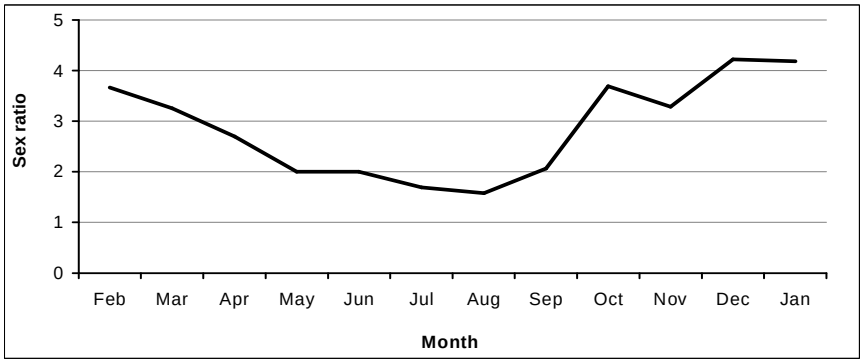

Figure 3: Monthly evolution of sex-ratio of *Pagellus erythrinus* in the Gulf of Tunis.

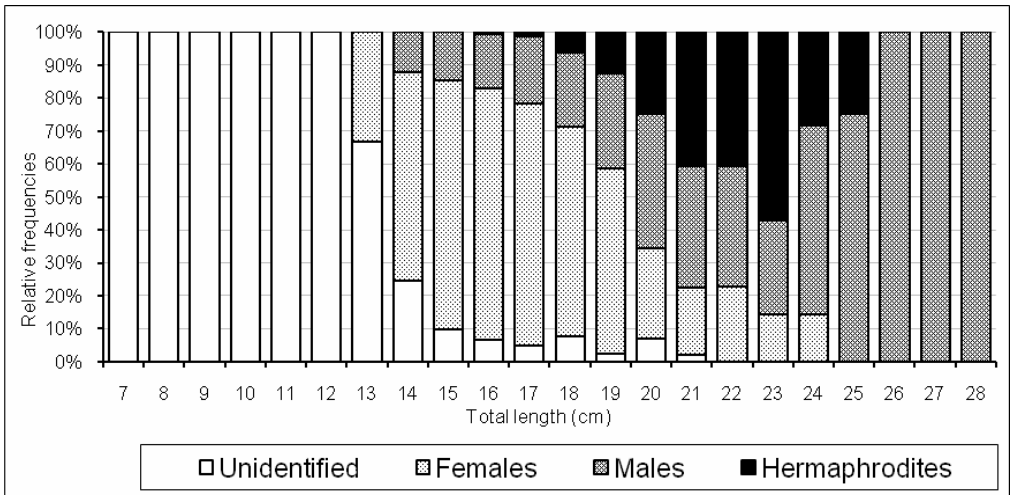

Figure 4: Length-frequency by sex of *Pagellus erythrinus* in the Gulf of Tunis.

(Hashem & Gassim, 1981) females represent 63.7%, in the Adriatic 84% (Rijavec & Županović, 1965) and in the coast of Canary Islands 2.63:1 (Pajuelo & Lorenzo, 1998).

The proportion of hermaphrodite found by macroscopic observation is in the order of 8% and is close to the results of Županović & Rijavec (1980): 7.2% in the Adriatic, and Pajuelo & Lorenzo (1998): 6.4% in the Atlantic.

Bannerot *et al.* (1987) explored the relationship between protogyny and susceptibility to overfishing which revealed that a limited sperm supply make protogynous populations more vulnerable to overexploitation than it do gonochoristic populations. However, some protogynous fish compensate the removal of males from their populations through sex change processes (Shapiro, 1981). In agree with these results, the monthly evolution of the sex-ratio in the Gulf of Tunis shows that during the reproductive period there are more males.

The size-sex structure is mainly determined by the nature of the sex change from females to males. The

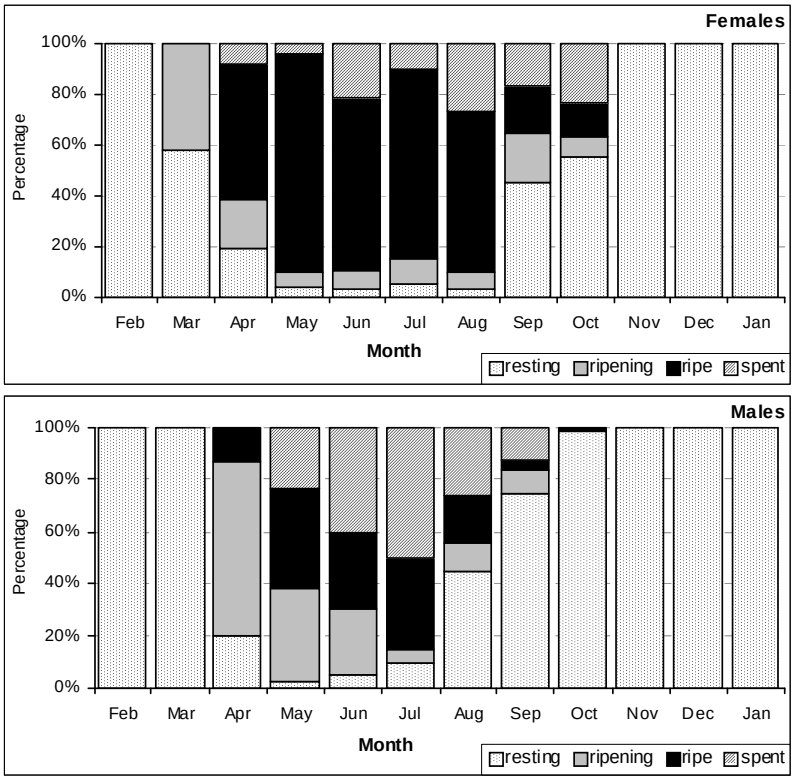

Figure 5: Monthly evolutions of the frequency of gonad maturity stage of *Pagellus erythrinus* in the Gulf of Tunis.

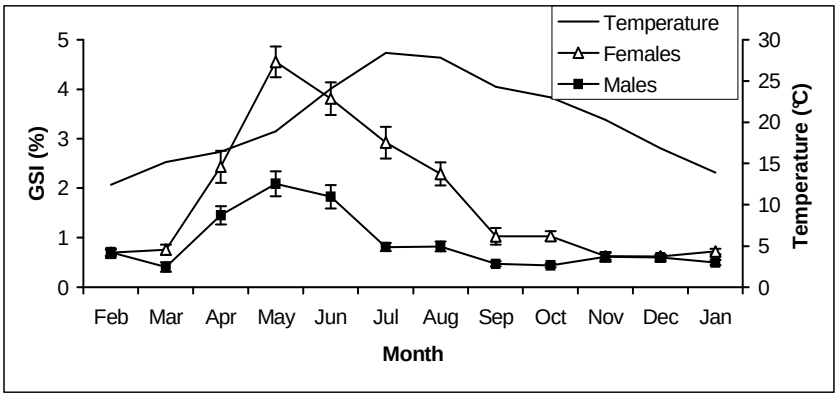

Figure 6: Monthly evolutions of the GSI (mean ± SE) of *Pagellus erythrinus* by sex and sea surface temperature (SST) in the Gulf of Tunis.

absence of females in the largest size classes (>24 cm) implies that, in the Gulf of Tunis, sex conversion seems to occur in all fish. The females change sex at the size class 17-18 cm of total length. This result agrees with that found in the central Mediterranean: 17-18 cm with age of 3 years (Relini *et al.*, 1999) and in the Adriatic 17 cm with age 3-4 years (Županović & Rijavec, 1980

According to the gonad macroscopic stages and the GSI, it is evident that *P. erythrinus* in the Gulf of Tunis spawns from April to October with a peak in May-July. The spawning period is extended to 7 months. A longer spawning period also indicates that favourable environmental conditions for hatching and larval development can be available for a longer period (Gonçalves & Erzini, 2000). In the Gulf of Tunis, *P. erythrinus* spawning started as SST increases and was reduced and after stopped by the temperature decrease. Our result is compared with literature data for the Mediterranean in Table III. In the Mediterranean, spawning takes place from April to September with a peak in May-June (Larrañeta, 1964; Girardin & Quignard, 1985; Papaconstantinou *et al.*, 1988; Livadas, 1989; Ghorbel, 1996). In the

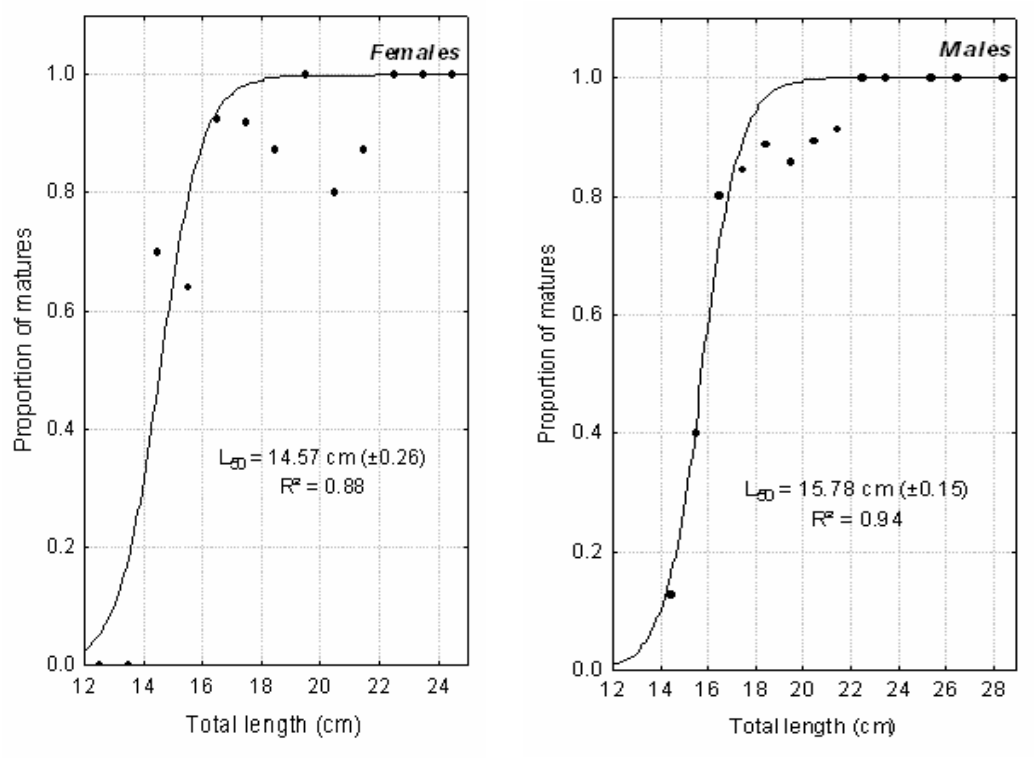

Figure 7: Sexual maturity ogive of *Pagellus erythrinus* in the Gulf of Tunis.

Table II: Estimates of total length (cm) at first (L_{50}) and at full (L_{95}) maturity, as a function of sex of *Pagellus erythrinus* in the Gulf of Tunis.

Sex	L_{50}	L_{95}	±SE	r^2	N
Females	14.6	16.6	0.26	0.88	175
Males	15.8	18.1	0.15	0.94	128

Table III: Spawning period and length at first maturity L_{50} (in total length TL in cm) according to several authors.

Area	Spawning period	Length at first maturity		Authors
		Females	Males	
Gulf of Tunis	April-October	14.6	15.8	Present study
Gulf of Gabès	May-July	13.55	14.59	Ghorbel, 1996
Tunisian waters	April-July	14.0	14.5	Ghorbel and Ktari, 1982
Gulf of Lyon	June-August	14-17	14-17	Girardin, 1978, 1981
Cretan shelf[1]	Spring-Summer	15.47 FL=13.4	16.42 FL=14.2	Somarakis and Machias, 2002
South Portugal	May-August	17.35	18.03	Santos *et al.* 1995
Canary Islands	April-September	17.4	23.2	Pajuelo and Lorenzo, 1998

[1]: Estimated by the author in fork length: FL, and we have transformed in total length by the equation given by the author: TL (mm) = - 3.36 + 1.18 FL (mm).

Atlantic, spawning occurs in spring, extending sometimes until summer (Pajuelo & Lorenzo, 1998).

The lengths at first maturity of the common pandora in the Gulf of Tunis (females 14.6 cm, males 15.8 cm) are close to that estimated in the Gulf of Lyon (Girardin, 1978, 1981) (Table III). Howerver, they are higher than that found in Tunisian waters (Ghorbel & Ktari, 1982) and in the Gulf of Gabès (Ghorbel, 1996) and lower than the values of the Atlantic (Santos *et al.* 1995; Pajuelo & Lorenzo,

1998). Females reach first maturity at a length smaller than that of males, which seems to be explained adequately by protogyny.

The inter-population variation in length at first maturity seems to be linked to growth differences of populations that are affected by environmental factors such as temperature and food quality and availability. Fish of common pandora attain maturity in the nearest area (Gulf of Gabès) at the age of 1.74 years for females and 2.19 years for males (Ghorbel, 1996). In the other Mediterranean areas, same results are shown and the first maturity is between the first and the third years of life (Larrañeta, 1964; Girardin & Quignard, 1985; Mytilinéou, 1989; Somarakis & Machias, 2002).

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