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REPRODUCTIVE CYCLE AND SIZE AT FIRST SEXUAL MATURITY OF COMMON PANDORA *PAGELLUS ERYTHRINUS* (SPARIDAE) FROM THE BAY OF MONASTIR (TUNISIA, CENTRAL MEDITERRANEAN)

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ABSTRACT

This study, dealing with the reproduction of the common pandora, Pagellus erythrinus (Sparidae) from the Bay of Monastir, focussed 640 specimens collected from September 2011 to August 2012. These specimens were sampled monthly during landings of coastal fisheries. Among the whole samples, 85 individuals were not sexually identified. The sexed specimens were composed of 260 males (46.84 %) and 295 (53.15 %). The monthly sex ratio showed significant differences between males and females. Females outnumbered males for sizes between 130 and 199 mm, while males outnumbered females from the 200 mm size up. Sexes combined, the length-weight relationship had a negative allometry. The reproduction period of the common pandora starts in April and ends in August. The gonadosomatic index (GSI) reaches the highest values in June for males and in July for females. Size at first maturity (TL) occurred at 167.5 and 153.2 mm for males and females respectively.

Keywords: *Pagellus erythrinus*, sex ratio, reproduction period, length at first sexual maturity

CICLO RIPRODUTTIVO E DIMENSIONI ALLA PRIMA MATURITÀ SESSUALE DI PAGELLO FRAGOLINO *PAGELLUS ERYTHRINUS* (SPARIDAE) NELLA BAI DI MONASTIR (TUNISIA, MEDITERRANEO CENTRALE)

SINTESI

Per il presente studio, incentrato sulla riproduzione del pagello fragolino, Pagellus erythrinus (Sparidae), nella baia di Monastir, sono stati considerati 640 esemplari pescati da settembre 2011 ad agosto 2012. I pesci sono stati prelevati mensilmente durante gli sbarchi dei pescatori locali. Il campione comprendeva 260 maschi (46,84 %) e 295 femmine (53,15 %), mentre 85 individui non sono stati identificati sessualmente. Il rapporto fra i sessi ha evidenziato differenze significative tra maschi e femmine. Le femmine superavano in numero i maschi per la lunghezza compresa tra 130 e 199 mm, mentre i maschi superavano in numero le femmine per le taglie superiori ai 200 mm. La relazione lunghezza-peso ha indicato per il campione totale (maschi e femmine) un'allometria negativa. Il periodo di riproduzione del pagello fragolino inizia ad aprile e finisce ad agosto. L'indice gonadico (GSI) ha raggiunto i valori più elevati nel mese di giugno per i maschi e in luglio per le femmine. La lunghezza alla prima maturità sessuale (TL) era pari a 167,5 mm per i maschi e 153,2 mm per le femmine.

Parole chiave: *Pagellus erythrinus*, rapporto fra i sessi, periodo di riproduzione, lunghezza alla prima maturità sessuale

INTRODUCTION

Common pandora, *Pagellus erythrinus* (Sparidae), is a demersal fish reported in the Black Sea, the Mediterranean Sea and the eastern Atlantic (Bonnet, 1969; Bauchot & Hureau, 1986; Fischer *et al.*, 1987; Fredj & Maurin, 1987). Investigations carried out in different Mediterranean areas showed that common pandora, preferably, inhabits on the continental shelf (Spedicato *et al.*, 2002) and lives on sandy, rocky or gravelly substrates (Mytélíneou, 1989). Depending on size, common pandora is widely distributed from shallow coastal waters to 300 m depth. (Orsi Relini & Romeo, 1985; Somarakis & Machias, 2002; Spedicato *et al.*, 2002).

The biology of common pandora was studied in different regions; such as the Gulf of Lion (Girardin & Quignard, 1985), the Ionian Sea (Papaconstantinou *et al.*, 1988), the Aegean Sea (Metin *et al.*, 2011; Moutopoulos *et al.*, 2013), the western Mediterranean (Valdés *et al.*, 2004), the central Adriatic (Zei & Zupanović, 1961) and the south of the Mediterranean along the Algerian coast (Lachehab, 2006).

In Tunisia, studies on growth and reproduction were conducted on common pandora from the Gulf of Gabès (Ghorbel, 1996; Ghorbel & Ktari, 1982; Ghorbel *et al.*, 1997) and the Gulf of Tunis (Zarrad *et al.*, 2010). Fassatoui & Romdhane (2010) studied the genetic variability in relation to the size of common pandora from the northern coast of Tunisia. In spite of the presence of *P. erythrinus* along the Tunisian coasts, there are no studies related to the biology of populations in the eastern fishing area, which is a transition zone between the northern coast and the Gulf of Gabès.

Consequently, the aim of our study is to determine the reproduction period and the size at first sexual maturity of common pandora from the Bay of Monastir.

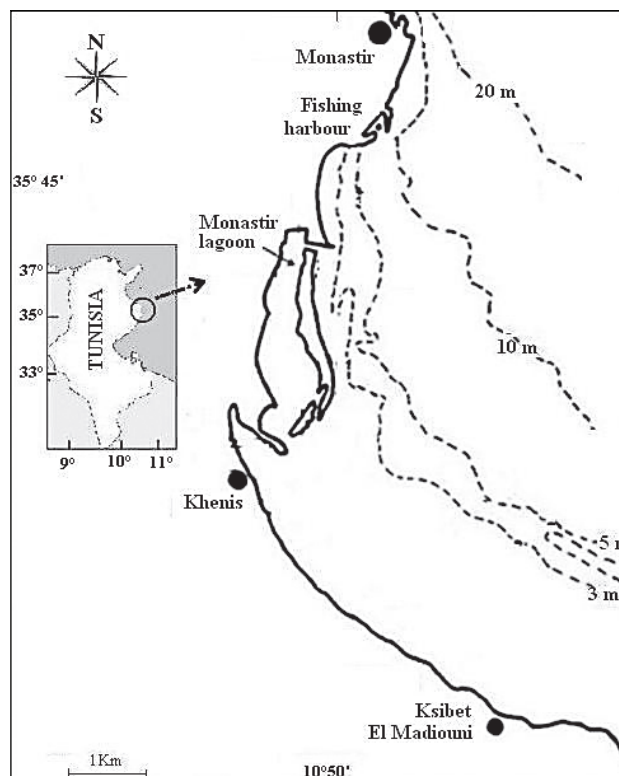


Fig. 1: Location of the Bay of Monastir; • - sampling sites.
Sl. 1: Lokacija zaliva Monastir; • - mesta vzorčenja.

MATERIALS AND METHODS

Sampling area

The sampling area, Bay of Monastir, is located in the Gulf of Hammamet, geomorphologic transition zone be-

Tab. 1: Macroscopic scale adopted to determine stages of gonadal development of *Pagellus erythrinus*.

Tab. 1: Lestvica za makroskopsko določanje zrelosti moških in ženskih gonad ribona (*Pagellus erythrinus*).

Stages	Female	Male
I: Immature	Ovary small, thin filament, transparent, invisible oocytes	Testes thin, white, slightly translucent
II: Sexual resting	Close to the stage I, larger volume, light pink colour	Close to the stage I, larger volume
III: Gonadal maturation	Gonad large, light orange to dark, ovarian granular, oocytes easily visible through the membrane	Testicles soft and white, flow of a whitish liquid after incision
IV: Mature gonads and spawning	Ovary very large, occupying almost the entire abdominal cavity, very thin ovarian membrane. Oocytes easily visible and expelled at the slightest pressure	Testes white, occupy the total abdominal cavity, sperm flows following a slight pressure
V: Post-spawning	Ovary flaccid, vascularized, pink salmon colour, oocytes smaller with presence of hyaline spaces	Flaccid testes slightly vascularized

tween the northern region of Tunisia and the southern Gulf of Gabès (Fig. 1). This bay is characterized by the occurrence of a herbarium of *Posidonia oceanica*, which constitutes a spawning and nursery biotopes for numerous vertebrate and invertebrate species (Ben Mustapha & El Abed, 2002). Beyond the *Posidonia* meadow and from a depth of 30 m, coralligenous biocenoses can be found on sandy substrate (Ben Mustapha & Afli, 2002). The Bay of Monastir, submitted to a very intense fishing activity, provides 44 % of the national fish production (Anonymous, 2012). The exploitation of bio-resources in this fishery implements different fishing gear targeting a variety of species with different lifespan living from the shallow coastal waters to the open sea.

Biological data

A total of 640 specimens were collected from September 2011 to August 2012 once or twice a month. The total length (TL; nearest 0.1 mm) and different weights (W, nearest 0.01 g) of each individual were recorded: Wt - total mass, Wev - eviscerated fish mass, Wg - gonad mass and Wl - liver mass. All specimens were sexed and sexual maturity was determined through the macroscopic observation of the gonads. Five stages were identified: I - immature, II - sexual resting, III - gonadal maturation, IV - mature gonads and spawning, V - post-spawning (Fehri-Bedoui & Gharbi (2008) (Tab. 1).

The sex ratio (SR, female vs. male) was calculated monthly according to the size of the fish:

$$SR = \frac{f}{m + f} \times 100$$

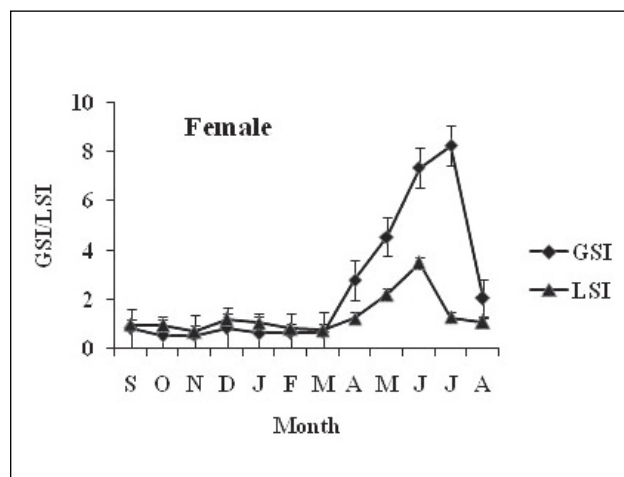


Fig. 2: Monthly variations of the gonado-somatic index (GSI) and liver-somatic index (LSI) of *Pagellus erythrinus* females in the Bay of Monastir.

Sl. 2: Mesečne varijacije gonado-somatskega indeksa (GSI) in jetno-somatskega indeksa (LSI) samic ribona (*Pagellus erythrinus*) v zalivu Monastir.

where m is number of males and f is number of females. The sex ratios, observed by month and by size classes, were statistically tested for significant deviations from the expected 1:1 ratio F using a test:

$$\chi^2_{obs} = (m^2/F) + (f^2/F) - F$$

$$F = (m + f)/2$$

In order to monitor the sexual cycle and determine the spawning period, the percentage of different stages of sexual maturity and the average of the gonado-somatic index (GSI) were calculated monthly for both females and males:

$$GSI = (Wg/Wev) \times 100$$

During reproduction fish undergoes physiological changes due to the mobilization of its energetic reserves. Thus, the average liver somatic index (LSI) and the average of the condition factor (Kc) were calculated monthly for females and males:

$$LSI = (Wl/Wev) \times 100$$

$$Kc = (Wev/TL^b) \times 100$$

The allometric constant b is determined from the length-weight relationship:

$$Wt = a \times TL^b$$

The size at first maturity is the size at which 50 % of individuals are mature (TL_{50}). During the reproduction

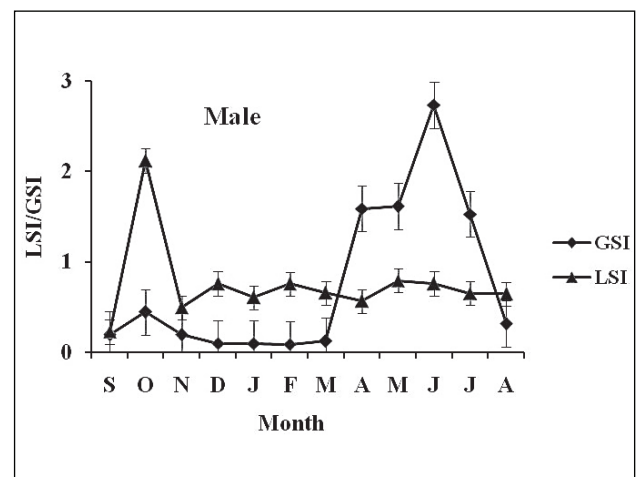


Fig. 3: Monthly variations of the gonado-somatic index (GSI) and liver-somatic index (LSI) of *P. erythrinus* males in the Bay of Monastir.

Sl. 3: Mesečne varijacije gonado-somatskega indeksa (GSI) in jetno-somatskega indeksa (LSI) samcev *P. erythrinus* v zalivu Monastir.

season, the collected individuals were classified as mature and immature individuals. Mature individuals with gonads in stages III and IV were classified by size class at an interval of 10 mm. The proportions of mature individuals (Pr) and their corresponding size classes (TL) were adjusted to a logistic curve (Saila et al., 1988) such as:

$$Pr = 1/(1 + e^{-r(TL-TL_{50})})$$

RESULTS

Sex ratio

Total length of males and females ranged from 110 to 270 mm. A number of 85 individuals were unsexed ($110 \leq TL_{mm} \leq 200$). Of 555 specimens, 260 (46.84 %) were males and 295 (53.15 %) were females. The monthly sex ratio showed significant differences ($= 279.7 > = 3.84$) (Tab. 2).

Females outnumbered males for sizes between 130 and 199 mm, while males outnumbered females from the 200 mm size with significant differences (Tab. 3).

Sexual cycle, gonado-somatic index, liver-somatic index and condition factor

Macroscopically, different stages of gonadal development were easily identified in both sexes. The monthly values of GSI were ranged from 0.39 to 7.87 in females and from 0.25 to 2 in males (Figs. 2, 3). In females, the GSI values were low from September to March; this period corresponds to two stages of the reproductive cycle,

the post spawning and the sexual rest. The values of the GSI increased by the end of March and reached the maximum in July (7.87). This period corresponds to the maturation of the gonads; it is followed by the spawn which extends to August. Statistically, the GSI values showed high significant differences ($p < 0.001$) for both sexes.

In females, the gonadal maturation period extends from March to June, while the spawning period lasts only two months (July-August). In males, changes in the GSI were similar to those of females. It appears that there is simultaneity in the chronology of the various gonadal stages. However, the males were fluent one month before female spawning.

In the Bay of Monastir, the reproduction period of *P. erythrinus* in spring and summer was confirmed by the monthly percentages of the different stages of sexual maturity in both sexes (Figs. 4A, B). In females, the curve of the LSI showed the same trend as the GSI. It exhibited low values (0.6 to 1.3) out of the reproduction period (September to March), which increased (from 1.24 to 3.4) during the gonadal maturation stage (April to June) and decreased during the spawning period (Fig. 2). In contrast, in males the LSI had the highest value (2) in post spawning and decreased and varied slightly during the other stages (Fig. 3).

The growth parameter b obtained from the length-weight relationship of common pandora ($W_{ev} = 0.03 \times TL^{2.72}$, where a is 0.03 and b is 2.72), calculated from 640 specimens, allowed us to calculate the condition factor (Kc) for both sexes. The Kc presented slight monthly variations: $2.47 \leq Kc_{\sigma} \leq 3.04$; $3.33 \leq Kc_{\varphi} \leq 3.81$ (Tab. 4). The lowest values were recorded in January for

Tab. 2: Monthly variations of the sex ratio (SR) of *P. erythrinus* in the Bay of Monastir. N = number, * = statistically significant difference at $p < 0.05$.

Tab. 2: Mesečne varijacije v razmerju spolov (SR) ribona (*P. erythrinus*) v zalivu Monastir. N = število, * = statistično značilna razlika pri $p < 0,05$.

Month	N _♂	N _♀	Total	SR	χ^2_{obs}	p
Sept	7	23	30	76.66	23.53	*
Oct	9	6	15	40.00	8.10	*
Nov	11	3	14	21.42	11.57	*
Dec	21	27	48	56.25	24.75	*
Jan	22	24	46	52.17	23.08	*
Feb	16	27	43	62.79	24.31	*
Mar	27	45	72	62.5	40.50	*
Apr	51	37	88	42.04	46.22	*
May	51	39	90	43.33	46.60	*
Jun	20	15	35	42.85	18.21	*
Jul	15	42	57	73.68	41.28	*
Aug	10	7	17	41.17	9.09	*
Total	260	295	555	53.15	279.7	*

Tab. 3: Sex ratio variations (SR) according to size of *P. erythrinus* in the Bay of Monastir. TL = total length, N: = number, ** = statistically significant differences at $p < 0.05$, - = χ^2 test non applicable.

Tab. 3: Variacije v razmerju spolov (SR) ribona (*P. erythrinus*) v zalivu Monastir. TL = skupna dolžina, N = število, ** = statistično značilna razlika pri $p < 0,05$, - = test χ^2 ni apliciran.

TL (mm)	N _♂	N _♀	Total	SR	χ^2_{obs}	p
110-119	3	1	4	25.00	-	-
120-129	10	9	19	47.36	9.55	**
130-139	5	11	16	68.75	10.25	**
140-149	7	16	23	69.56	15.02	**
150-159	19	45	64	70.31	42.56	**
160-169	10	46	56	82.14	51.14	**
170-179	10	13	23	56.52	11.89	**
180-189	22	27	49	55.10	25.01	**
190-199	21	22	43	51.16	25.32	**
200-209	27	23	50	46.00	43.06	**
210-219	44	16	60	26.66	36.78	**
220-229	32	6	38	15.78	9.57	**
230-239	10	4	14	28.57	7.07	**
240-249	6	1	7	14.28	1.00	**
250-259	1	1	2	50.00	-	-
260-269	13	0	13	0.00	3.00	**
270-279	2	0	2	0.00	-	-
300-309	1	0	1	0.00	-	-

both sexes, while the highest values were recorded during spring, in May for females and March for males.

Size at first sexual maturity

The sigmoid functions, linking the proportions of mature individuals and the total length of the fish allow to follow the degree of sexual maturity by size and to ac-

curately estimate the length TL_{50} - 153.2 mm for female and 167.5 for male with high correlation coefficients: $R^2_{\text{♀}} = 0.95$; $R^2_{\text{♂}} = 0.97$ (Figs. 5A, B).

DISCUSSION

Predominance of females between 130 mm and 190 mm in size and the predominance of the males having

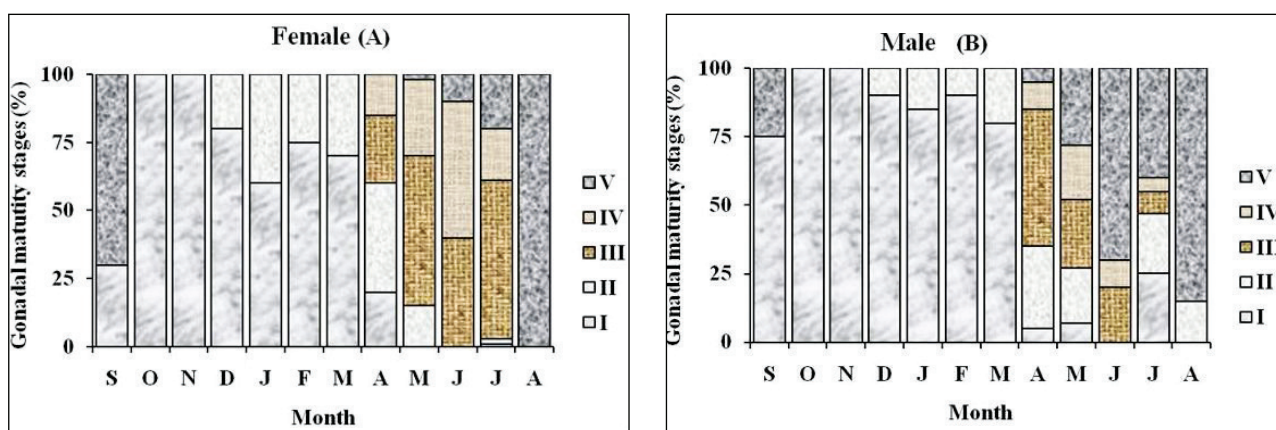


Fig. 4 (A-B): Monthly evolutions of the percentage of gonadal maturity stages of *P. erythrinus* (A) female and (B) male in the Bay of Monastir; maturity stages: I to V.

Sl. 4: Mesečne spremembe v deležih zrelosti gonad (A) ženskih in (B) moških osebkov *P. erythrinus* v zalivu Monastir; stopnje zrelosti I do V.

Tab. 4: Monthly variations of the condition factor (Kc) of *P. erythrinus* female and male in the Bay of Monastir.
Tab. 4: Mesečne spremembe kondicijskega faktorja (Kc) moških in ženskih osebkov *P. erythrinus* v zalivu Monastir.

Month	Kc _♀	Kc _♂
Sept	3.7±0.39	0.73±0.36
Oct	3.6±0.35	2.66±0.2
Nov	3.5±0.23	2.77±0.14
Dec	3.55±0.42	2.94±0.5
Jan	3.33±0.41	2.47±0.13
Feb	3.54±0.35	2.7±0.35
Mar	3.52±0.43	3.04±0.43
Apr	3.74±0.37	2.84±0.23
May	3.81±0.29	2.77±0.41
Jun	3.46±0.19	2.62±0.13
Jul	3.59±0.35	2.74±0.15
Aug	3.65±0.16	2.84±0.25

upper sizes suggests a probable sexual inversion of female toward male. These observations were confirmed by the presence of a protogynous hermaphroditism in this species found along the Tunisian coast in the Gulf of Gabès (Ghorbel & Ktari, 1982; Ghorbel, 1996) and the Gulf of Tunis (Zarrad *et al.*, 2010). The protogyny of common pandora was observed in the Mediterranean (Papaconstantinou *et al.*, 1988; Mytilinéou, 1989) and in the Eastern Atlantic (Pajuelo & Lorenzo, 1988).

For the whole collected sample (sexes combined), the length-weight relationship has a negative allometry. This result corroborates with those found in the eastern Mediterranean (Livadas, 1989), in the Aegean Sea (Hoşsucu & Çakir, 2003; Metin *et al.*, 2011) and in the Adriatic (Rijavec & Lupanovic, 1965). However, a

positive allometry in length-weight relationship, was observed on the common pandora from the Atlantic (Pajuelo & Lorenzo, 1998) and in the central Mediterranean (Ghorbel, 1996), Adriatic (Bolje, 1992) and Aegean Seas (Mytilinéou, 1989) (Tab. 5). This disparity in findings could be attributed to the differences in the impact of the protogyny on the growth of both sexes. Similar patterns were observed in some populations from the Atlantic and the Mediterranean due to the fact that the growth of males and females showed significant differences (Hoşsucu & Çakir, 2003; Coelho *et al.*, 2010).

Monthly variations of GSI showed that the reproduction season occurred from April to August with a peak in June for males and in July for females. This period was reported by other authors who investigated the Mediterranean basin and the adjacent areas (Tab. 5). Ghorbel (1996) noted that *P. erythrinus* spawns between May and July in the Gulf of Gabès. Zarrad *et al.* (2010) reported that the reproduction of this Sparidae extended from April to October in the Gulf of Tunis. Common pandora required a long spawning period with two peaks, in June and October (Metin *et al.*, 2011). Tsikliras *et al.* (2010) reported a summer reproduction period extending between June and August for the common pandora of the Adriatic Sea. Papaconstantinou *et al.* (1988) noted that common pandora spawned from June to September in the Ionian Sea. The reproduction over several consecutive months was also reported in the eastern Atlantic (Tab. 5). A period of reproduction was recorded from March to July in the south of Portugal (Coelho *et al.*, 2010). A longer reproductive period (April–September) was observed for the same species off the Canary Islands (Pajuelo & Lorenzo 1998).

Monthly variations in the liver somatic index, showing the same trend as those of the GSI in the females, indicate that this fish probably stores its energetic reserves in liver during the gonadal maturation period. Such reserves might be used for the energetic requirements of the spawning. Slight variations of the condition factor

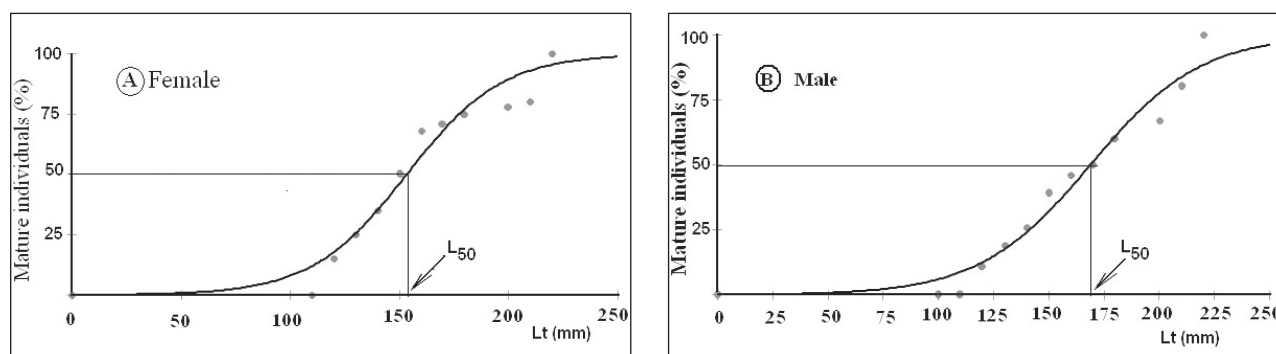


Fig. 5: Logistic curves for estimation of the size at first sexual maturity (L_{50}) of *P. erythrinus* (A) female and (B) male in the Bay of Monastir.

Sl. 5: Logistične krivulje za oceno dolžine ob prvi spolni zrelosti, L_{50} (A) ženskih in (B) moških osebkov *P. erythrinus* v zalivu Monastir.

Tab. 5: Spawning period (framed months) and length at first maturity (TL_{50}) according to different geographical regions. Sl. 5: Obdobje drstenja (uokvirjeni meseci) in velikost ob prvi spolni zrelosti (TL_{50}) v različnih geografskih regijah.

Area	Spawning period	TL ₅₀ (mm)		Source
		♂	♀	
Northern Mediterranean				
Western Gulf of Lion	J-F-M-A-M- J-J-A-S -O-N-D	140, 170	140, 170	Girardin & Quignard (1985)
Central Adriatic Sea	J-F-M-A-M- J-J-A-S -O-N-D	-	-	Tsikliras <i>et al.</i> (2010)
Eastern Aegean Sea	J-F-M-A-M- J-J-A-S -O-N-D	150	113	Metin <i>et al.</i> (2011)
Southern Mediterranean				
Gulf of Tunis	J-F-M- A-M-J-J-A-S -O-N-D	157.8	145.8	Zarrad <i>et al.</i> (2010)
Gulf of Gabès	J-F-M-A- M-J-J-A -S-O-N-D	145.9	135.5	Ghorbel (1996)
Bay of Monastir	J-F-M- A-M-J-J-A-S -O-N-D	167.5	153.2	Present study
Eastern Atlantic				
Southern Portugal	J-F- M-A-M-J-J-A -S-O-N-D	175.8	172.8	Coelho <i>et al.</i> (2010)
Canary Islands	J-F-M- A-M-J-J-A-S -O-N-D	174	232	Pajuelo & Lorenzo (1998)

were observed over the year even during the reproduction period. Probably, the summer environmental factors, long period of sunlight, high temperature as well as abundant food, maintain a normal metabolic activities of the common pandora as it was reported for fishes in general (Brett, 1979).

The size at sexual maturity of *P. erythrinus* showed changes related to Tunisian areas: TL_{50} is 153.2 mm and 167.5 mm for females and males, respectively. These values are higher than that found for the same species in the Gulf of Tunis ($TL_{50♀}$ = 146 mm, $TL_{50♂}$ = 146 mm) (Zarrad *et al.*, 2010). Ghorbel (1996) reported a significantly earlier onset of sexual maturity for specimens from the Gulf of Gabès ($TL_{50♀}$ = 135.5 mm, $TL_{50♂}$ = 145.9 mm) (Tab. 5). The regional variability in size at first sexual maturity of this species is also observed in the Aegean Sea: $TL_{50♀}$ = 113 mm and $TL_{50♂}$ = 150 mm (Metin *et al.*, 2011). Girardin (1981) and Girardin & Quignard (1985) observed two sizes at first maturity (LT_{50} = 140 and 170 mm) for both females and males in the Gulf of Lion. In the eastern Atlantic, TL_{50} of common pandora is higher

than that observed in Mediterranean. For both sexes it was 180 mm in Southern Portugal (Santos *et al.*, 1995). Coelho *et al.* (2010) reported in the same area different TL_{50} values for male and female ($TL_{50♂}$ = 175.8 mm, $TL_{50♀}$ = 175.8 mm). Also, the size at first maturity reaches a higher value (TL = 232 mm) in common pandora population of the Canary Islands (Pajuelo & Lorenzo, 1998).

Common pandora from the Bay of Monastir exhibited the spawning period similar to this reported from other regions of the Mediterranean and eastern Atlantic. However, the species reached sexual maturity at different sizes according to sexes and geographical distribution. The common pandora maturity seems to be regulated by two geographical gradients, the North-South as well as East-West gradient.

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REPRODUKTIVNI CIKLUS IN VELIKOST OB PRVI SPOLNI ZRELOSTI RIBONA *PAGELLUS ERYTHRINUS* (SPARIDAE) V ZALIVU MONASTIR (TUNIS, OSREDNJE SREDOZEMLJE)

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POVZETEK

V študiji o razmnoževanju ribona, *Pagellus erythrinus* (Sparidae), v zalivu Monastir je bilo od septembra 2011 do avgusta 2012 mesečno vzorčenih skupno 640 osebkov v ulovih priobalnega ribolova. Določili smo 260 samcev (46,84 %) in 295 samic (53,15 %), 85 osebkov je bilo spolno nedoločljivih. V mesečnih razmerjih med spoloma so bile znatne razlike. Ženski osebki so prevladovali v dolžinskem razredu (TL) med 130 in 199 mm, moški osebki pa od 200 mm navzgor. V odnosu dolžina – teža kaže skupni vzorec (moški in ženski osebki) negativno alometrijo. Obdobje razmnoževanja traja od aprila do avgusta z viškom gonado-somatskega indeksa (GSI) v juniju za samce in juliju za samice. Velikost (TL) ob prvi spolni zrelosti je dosežena pri 167,5 mm za samce in 153,2 mm za samice.

Ključne besede: *Pagellus erythrinus*, razmerje spolov, reprodukcijsko obdobje, dolžina ob prvi spolni zrelosti

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