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ORIGINAL ARTICLE

Age, growth and reproductive dynamics of the common pandora, *Pagellus erythrinus* from GFCM-GSA 26, Mediterranean Sea, Egypt

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Abstract
Sparid fishes (Sparidae) are one of the most important species due to its highly economic value in Egyptian Mediterranean waters GFCM-GSA26. They contribute about 8% of the total Mediterranean catch and consist of at least 13 species exploited by more than one fishing gear. The common pandora, *Pagellus erythrinus* in GSA26 is an important species with a very high commercial value. It is a target of the trawl fleet operating during the whole fishing season. There are no significant differences between males and females age and growth parameters. Age was determined from the whole otolith readings; the ages observed were covered five age groups from 0 to 4 years, corresponding to 7.0 and 22.9cm of total length (TL). The von Bertalanffy growth parameters for pooled data were L_∞=26.39 cm, k=0.34 year^{-1} and t_0= −0.79 year. Reproductive biology of *P. erythrinus* in GSA26 was investigated and the monthly gonado-somatic indices and the variations in maturity stages indicated that *P. erythrinus* spawns in the spring and summer from March to August. The overall sex ratio throughout the study period was 1:1.29 males to females, which was significantly different from 1:1. The size at 50% sexual maturity was 14.8 and 14.2cm TL for males and females respectively. It was found that about 40% of *P. erythrinus* were caught before reaching their first sexual maturity indicating that the current minimum legal length in GSA26 is not appropriate for managing this species. The study recommends reduction of fishing pressure especially during the spawning season and increase the mesh sizes of nets used.

Keywords: Mediterranean Sea, *Pagellus erythrinus*, Age determination, Sex ratio, Spawning season.

INTRODUCTION

Fishes of the family Sparidae, commonly known as seabreams, are demersal fishes inhabiting coastal waters and occupy a variety of trophic niches. They are widely distributed in the Atlantic, Indian and Pacific Oceans. Seabreams are common coastal fish species inhabiting tropical and temperate waters throughout the world. To date, 162 species of 38 genera have been ascribed to this family (Froese and Pauly 2022). Its members are carnivorous, marine, brackish, reef-associated and inhabit shallow coastal waters (Sommer et al. 1996).

In the Mediterranean area, seabreams are of great interest for fisheries and aquaculture where the gilthead seabream, *Sparus aurata*, has become one of the most important cultured species in the Mediterranean region. Most sparid fish species are usually appreciated as seafood with high commercial value. Despite the growing interest in these fishes, however, few studies on some aspects of their biology are available. Seabreams are represented in the Egyptian Mediterranean (GFCM-GSA 26) by at least 13 species and constitute up to 8% of the total catch (GAFRD annual statistical book, 2018). The common pandora, *Pagellus erythrinus* (Linnaeus, 1758), is a valuable species for aquaculture and fisheries. This species has a relatively wide distribution, inhabiting the Black and Mediterranean seas and from Norway to Angola (Bauchot & Hureau 1986). In the Egyptian Mediterranean waters, *P. erythrinus* is of very high commercial importance and is mainly captured by trawling and gill or trammel nets (Mehanna & Fattouh 2009; Mehanna 2011) with a mean annual production of 470 tons (GAFRD 2018).

Knowledge of the age, growth, and reproductive biology of a fish species is essential for effective

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fishery management (Mehanna 1996). Generally, the description of reproductive dynamics is a key focus for stock assessment since this information is ultimately required for sound management controls such as minimum legal lengths, closed season and closed area. Thus, understanding the reproductive biology of a species is the central aspect of providing sound scientific advice for fisheries management. Reproductive biology plays an important role in determining productivity and therefore a population's resiliency to exploitation by fisheries or to the perturbation caused by other human activities (Morgan, 2008). Although the common pandora is heavily studied in the Mediterranean region, it is sparsely studied in the Egyptian Mediterranean GFCM-GSA 26. The objective of this study is to provide information on age and growth, spawning seasonality, size at maturity, and sex ratio of common pandora in the Egyptian Mediterranean Sea GFCM-GSA 26 (Fig. 1) for a better understanding of the life cycle and dynamics of this species.

Material and Methods

Sampling: The fish samples were collected randomly from commercial landings in Borg El-Burullus (Fig. 2) landing site where 80% of the common pandora from GSA 26 are landed. A total of 337 males (7-22.8cm in total length) and 435 females (7-22.9cm in total length) of *Pagellus erythrinus* during the period from January to December 2019 were collected. The total length (TL) was measured to the nearest mm and the body weight (W) was recorded to the nearest g. The sex of each specimen was determined macroscopically after the dissection of specimens.

Age and growth: The whole otoliths immersed in glycerol were examined for age determination using a compound microscope and amplifications between 10 and 40x, with a black background and under reflected light. Each otolith was observed by three experienced researchers and a valid age was only attributed if the three age estimations were in agreement. Coefficient of Variation (CV), Absolute Percent Error (APE) and Percent Agreement (PA) were used to estimate the reading precision (Beamish & Fournier 1981). The length-weight relationship was estimated in a nonlinear power regression $W = aL^b$ (LeCren 1951) using the total length and total weight.

Growth was modeled according to the von Bertalanffy growth function (VBGF), which is expressed as: $L_t=L\infty\ (1-e^{-K(t-to)})$, where L_t is the total length at age t, $L\infty$ is the asymptotic length, k is the growth coefficient and t_0 is the theoretical age when $L_t=0$ (von Bertalanffy 1938).

The constants $L\infty$ and K were estimated using the Ford (1993)-Walford (1946) plot, while the constant "t_0" was estimated from the following formula: $\ln[1-(Lt/L\infty)]=-kt_0+kt$ (von Bertalanffy 1938). The growth performance index was computed to compare the von Bertalanffy growth of the *P. erythrinus* fish with other fish species according to the formula $Ø' = \text{Log } K + 2 \text{ Log } L\infty$ (Pauly & Munro 1984). The statistical analyses was performed using an Excel sheet and SPSS 22.

Sex ratio: The sex of each specimen was identified by examination of the gonads. The proportion of the two sexes relative to one another is used to calculate the sex ratio. The deviation from 1:1 null hypothesis was statistically tested by Chi-square test (χ^2).

Spawning season: The spawning period was determined through the examination of two variables: the percentage frequency of the maturity stages and the monthly variation in the gonado-somatic index. The gonad maturity stages were recorded using the Fantodji (1987) criteria with some modifications. Gonadal maturity stages were recognized, (I= immature; II= resting; III= developing; IV= ripe; V= ripe running; VI= spent). The average monthly gonado-somatic index (GSI) of both males and females is calculated according to Strum (1978) as follows: GSI = (Gonad weight)/(Body weight)*100.

Length (L_m) at first sexual maturity and length at first capture (L_c): The length at first sexual maturity (L_m); the length at which 50% of *P. erythrinus* reach their sexual maturity was estimated for males and females from the percentages of mature individuals (stages III, IV, V) and the proportion of mature individuals in each size class (1 cm intervals) was calculated. A

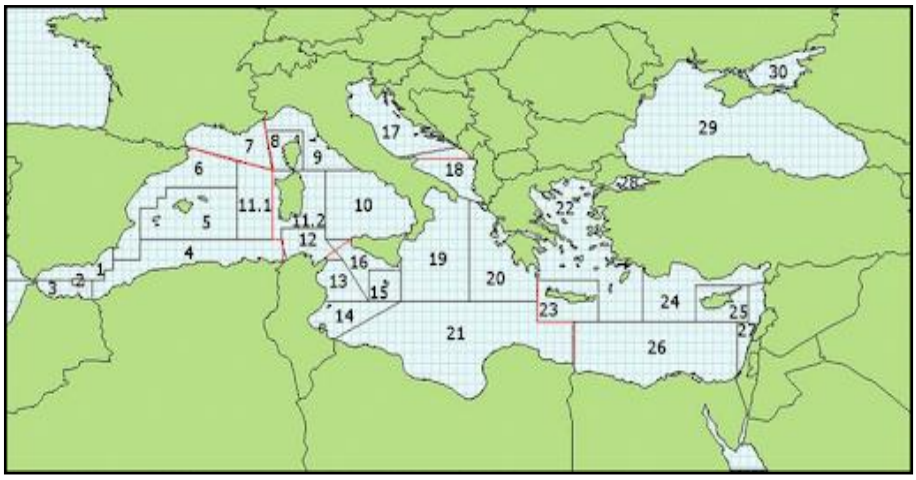

Fig.1. General Fisheries Commission of the Mediterranean sub areas (GFCM GSAs).

Fig.2. Egyptian Mediterranean coast with the mail landing sites.

logistic function relating the proportions of mature individuals to total length of the fish (Ghorbel et al. 2002) was used. This function of sigmoid shape is expressed as follows:

$$P = 1/\ 1 + e^{-(b + aTL)}$$

Where P is the proportion of mature individuals, TL is the total length in cm and a and b are constants. While the length at first capture (L_c) was determined by analyzing the probability curve of Pauly (1984).

Results and discussion

Age and growth: Age observations are essential for almost all aspects of the fishery investigation but particularly for studies on age, growth, production and population dynamics. A total of 772 otoliths (337 males and 435 females) were read and used in age and growth determination. Age was determined by counting the opaque rings on the otoliths. Alternative pairs of the translucent and opaque zones were considered a year annulus. The whole otolith readings indicated good agreement between the different estimates (agreement= 91.15%, CV= 4.27% and APE= 3.92%). Campana (2001) suggested that acceptable levels for APE and CV were 5.5% and 7.6%, respectively. Therefore, the present results are close to the acceptable values for both APE and CV. The maximum observed age was 4 years for males and females. The results revealed that there is no significant difference in back-calculated lengths between the two sexes ($P > 0.05$). The estimated maximum age was 4 years. Age group one was dominant (40 and 42% for males and females, respectively) followed by age group two (31 and 28% for males and females respectively) (Fig. 3).

A total of 853 specimens (337 males, 435 females, 60 hermaphrodites and 21 unidentified) were captured

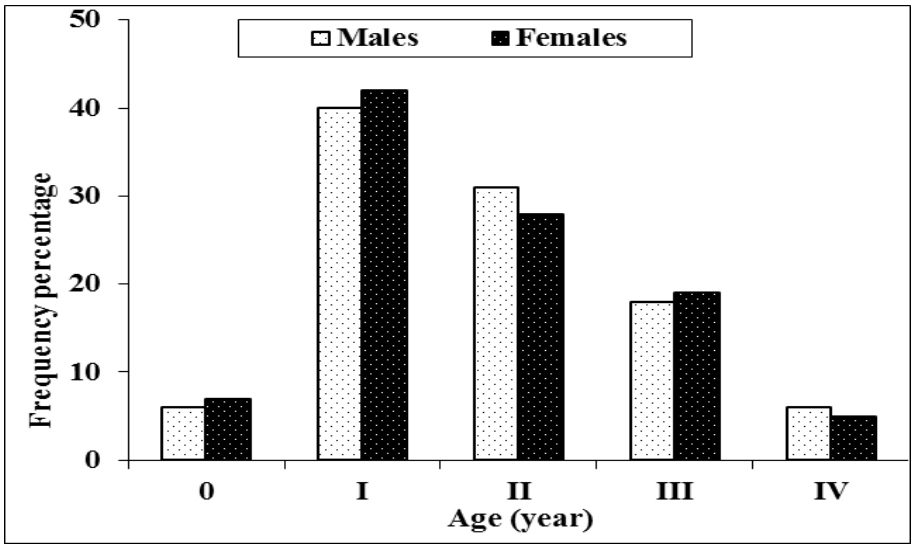

Fig.3. Age composition of *Pagellus erythrinus*, Mediterranean Sea, GSA 26.

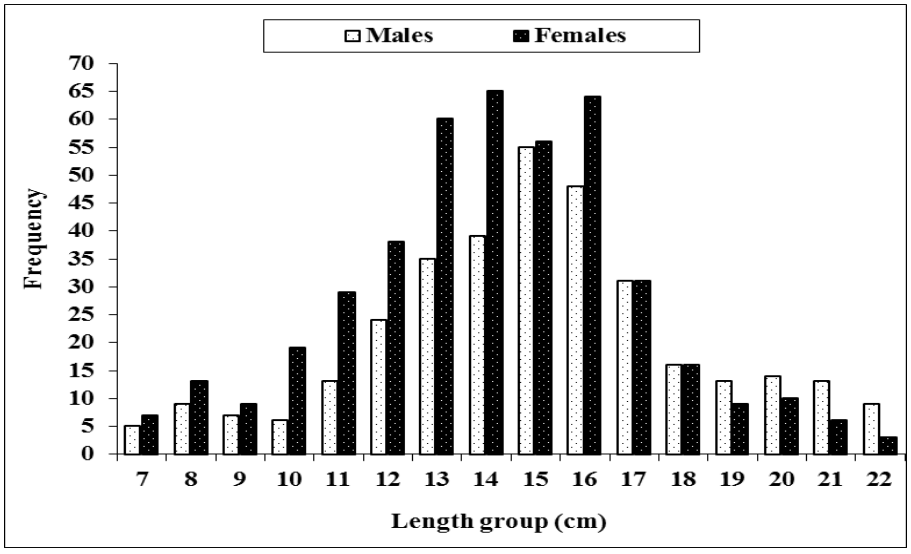

Fig.4. Length frequency distribution of *Pagellus erythrinus*, Mediterranean Sea, GSA 26.

during the study period. The length and weight frequency distribution ranged from 7 to 22.8cm TL and from 6 to 145g in weight for males and from 7 to 22.9cm TL (6.5-150 g in weight) for females. The length frequency distribution for *P. erythrinus* population showed that the most frequent size classes in males were 13-17cm (about 64%) whereas for females were 12-16cm (about 63%) (Fig. 4). Size frequency distribution between males and females was not significantly different (Kolmogorov–Smirnov two-sample test, $P > 0.05$).

There was no significant difference in the length-weight relationship between males and females (df=771, $t_s<t_t$). Values for b were 2.885 (r^2=0.98) for males and 2.847 (r^2=0.97) for females, which indicated negative allometric growth (t-test, $P<0.05$) (Fig. 5). The LWR for combined sexes was $W=0.0183\ L^{2.875}$ (r^2=0.98). The observed negative allometric growth of *P. erythrinus* in this study was similar to some previous studies (Andaloro & Giarritta 1985; Vassilipoulo et al. 1986; Livadas 1989; Özaydın 1997; Hoşsucu & Çakır 2003). The b-values are often 3.0 but may range between 2.5 and 3.5 (Ricker 1975). The LWR in fish is affected by several factors including gonad maturity, sex, diet, stomach fullness, differences in the observed length ranges of the caught specimen, and health as well as season and habitat (Ricker 1975; Froese 2006).

The growth model of the von Bertalanffy yielded

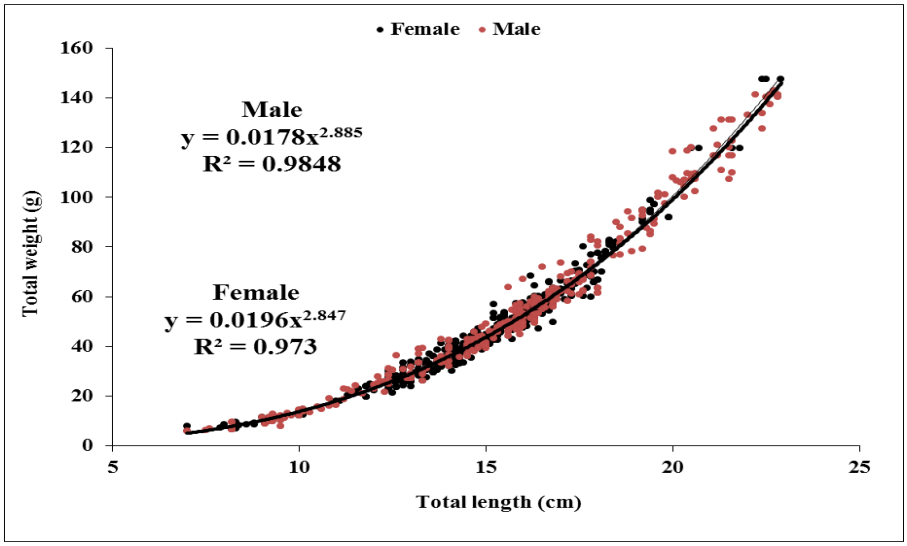

Fig.5. Length-weight relationship of *Pagellus erythrinus*, Mediterranean Sea, GSA 26.

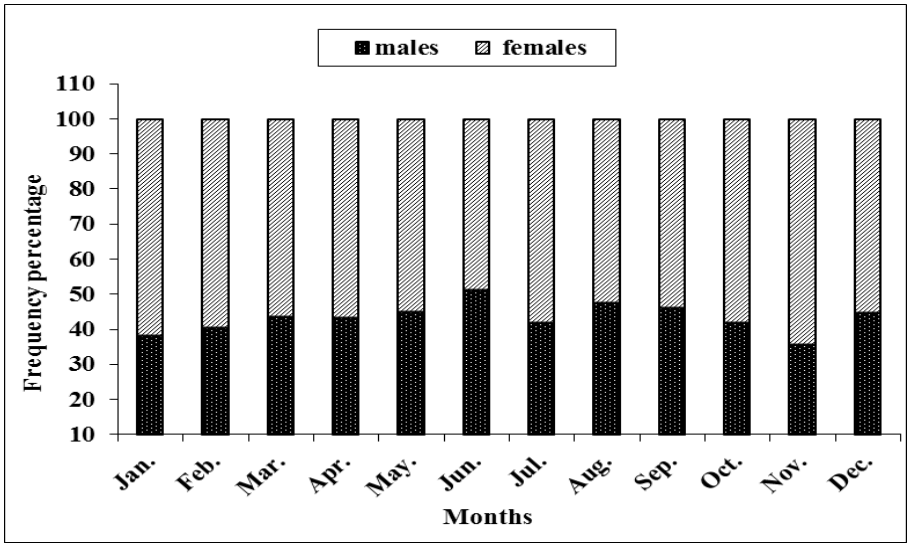

Fig.6. Sex-ratio as a function of total length of *Pagellus erythrinus*, Mediterranean Sea, GSA 26.

the following parameters K= 0.36y^{-1}, L∞= 26.39cm TL, and t_0= -0.79y for sexes combined. There is no significant difference between males and females in respect to the maximum length, longevity and growth parameters. Based on the resultant growth parameters, the growth performance index value (Ø') for *P. erythrinus* was 2.40 and this parameter has been calculated between 1.96 and 2.59 in previous studies (Girardin & Quignard 1985; Somarakis & Machias 2002; Hoşsucu & Çakır 2003).

Sex ratio: The overall sex ratio was 1:1.29 in favor of females which was significantly different from the theoretical sex ratio 1:1 (χ^2, *P<0.05*). Females were dominant all months except in June (Fig. 6) where males were the dominant (1:0.95), while in May, August, and September, the sex ratio in males and females is not significantly different from the theoretical sex ratio 1:1 (χ^2, *P>0.5*). The size-specific sex ratio of the common pandora revealed that the number of females was higher for lengths from 10.5 to 17.5cm and for 7.5, 8.5 and 27.5cm. While the number of males was higher for sizes between 24.5 and 26.5cm and for size 9.5 and 18.5cm. The percentages of males and females were equal for size 19.5cm (Fig. 7). The sex ratio differed statistically between the size classes (*P*=0.001). The sex ratio in our study showed the dominance of females, which can be explained by the protogynous hermaphroditic nature of

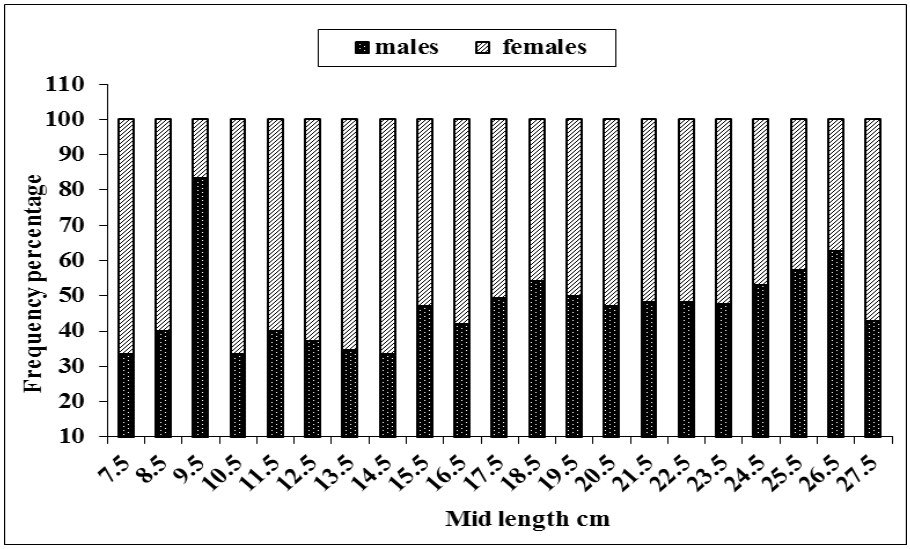

Fig.7. Sex-ratio as a function of total length of *Pagellus erythrinus*, Mediterranean Sea, GSA 26.

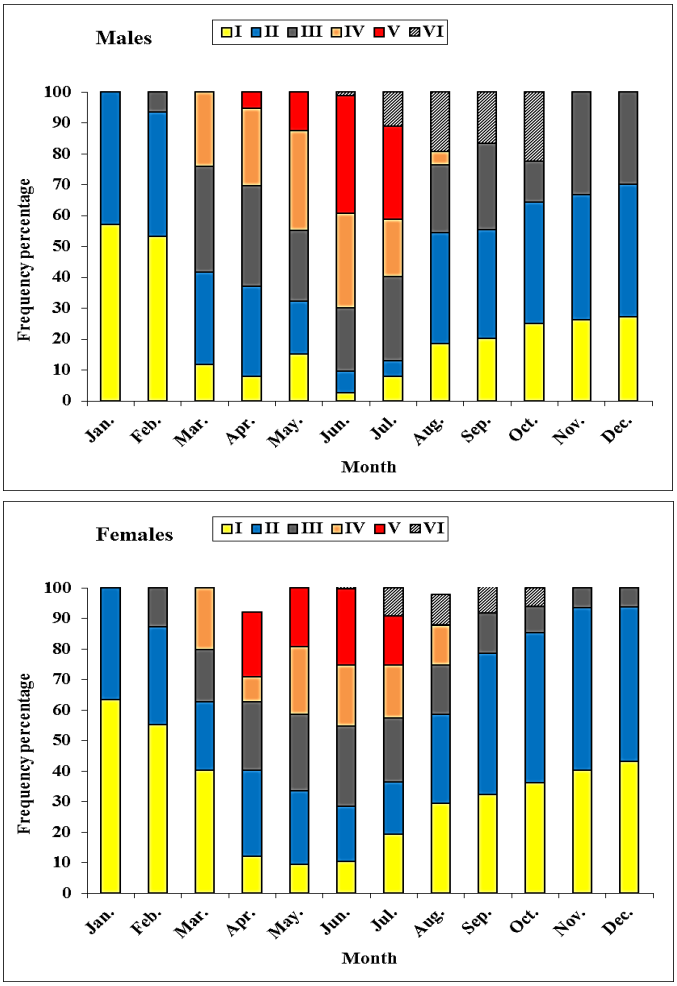

Fig.8. Monthly percentage of maturity stages of males and females for *Pagellus erythrinus*, Mediterranean Sea, GSA 26.

P. erythrinus. This prevalence of females has been reported in several areas in the Mediterranean (Vassilopoulou & Papacanstantinou 1986; Mytilineou 1989; Ghorbel 1996; Özaydın 1997; Pajuelo & Lorenzo 1998; Hossucu & Cakır 2003; Busalacchi et al. 2014; Mahdi et al. 2018; Lteif et al. 2020).

Reproductive cycle: To determine the reproduction period of *P. erythrinus*, monthly variations in both of maturity stages and gonado-somatic index values were used.

Monthly distribution of maturity stages: The gonads of 337 males and 435 females' *P. erythrinus* were used to evaluate the monthly variations in their maturity stages in the Mediterranean Sea GSA 26 (Fig. 8). It was obvious that for both sexes, the immature and mature stages (I & II) were found throughout the period of this study. The highest percentages were recorded in October, November, December and January. The mature stage III was observed with a high percentage from March to November for males and from April to July in females. The ripe stage IV and ripe running V first appeared in March for both sexes. The percentages of the ripe stage increased progressively and reached its highest values in May for stage IV and June for stage V. The spent males and females first appeared in June, with the highest percentages in October and September for males and females respectively.

Gonado-somatic index (GSI): The gonado-somatic index is used to study the spawning season by tracing changes in the gonad weight in relation to the total fish

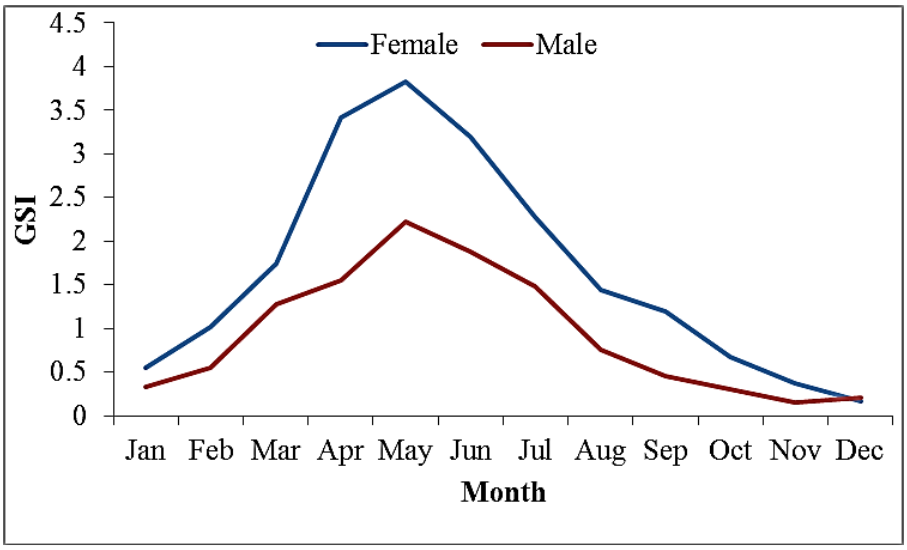

Fig.9. Mean monthly changes in gonado-somatic index for males and females of *Pagellus erythrinus*.

weight. Monthly variation in GSI of *P. erythrinus* from GSA 26 was evaluated (Fig. 8). The monthly GSI for each sex increased from January towards August with a peak in May and June, then it declined to December. The monthly values of GSI ranged between 0.19 and 3.82 in females and from 0.15 and 2.23 in males. The mean values reached the highest values from April to July (Fig. 9)

Spawning season: There is only one breeding season per year for common pandora, which takes place in spring and summer (March to August), where the highest values of GSI and the highest percentages of ripe gonads were recorded. These results are consistent with the findings of the previous studies. This period was reported by other authors who investigated the Mediterranean basin and the adjacent areas. Papaconstantinou et al. (1988) noted that common pandora spawned from June to September in the Ionian Sea. Ghorbel (1996) noted that *P. erythrinus* spawns between May and July in the Gulf of Gabès. A longer reproductive period (April-September) was observed for the same species of the Canary Islands (Pajuelo & Lorenzo 1998). Zarrad et al. (2010) reported that the reproduction of this species extended from April to October in the Gulf of Tunis. Tsikliras et al. (2010) reported a summer reproduction period extending between June and August for the common pandora in the Adriatic Sea. Common pandora required a long spawning period with two peaks, in June and October (Metin et al. 2011). A period of reproduction was recorded from March to July in the south of Portugal (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 in the Bay of Monastir, Tunis (Ben Smida et al. 2014).

Size at first sexual maturity and at first capture: Estimation of length at maturation and length at first capture is important for determining the optimum length for the catch. The size at 50% sexual maturity was estimated graphically where the maturation curve is constructed and length at maturity was estimated as the point on abscissa corresponding to the 50% point on the ordinate (Fig. 10). From the maturation curve, the length at first sexual maturity of common Pandora in GSA 26 was 14.8 and 14.2cm TL for males and females, respectively. These lengths lie in the age group I. It is evident that a considerable proportion (40%) of common pandora catch didn't reach the first sexual maturity. Therefore, to protect this species and to enable it to share at least one time in reproduction, the mesh sizes must be re-evaluated. The estimated L_m indicates that the current minimum legal length in Egyptian Mediterranean waters is not appropriate for managing this species.

The values of length at 50% maturity varied among different regions. Metin et al. (2011) recorded lengths at first maturity to be 11.30 cm for females and

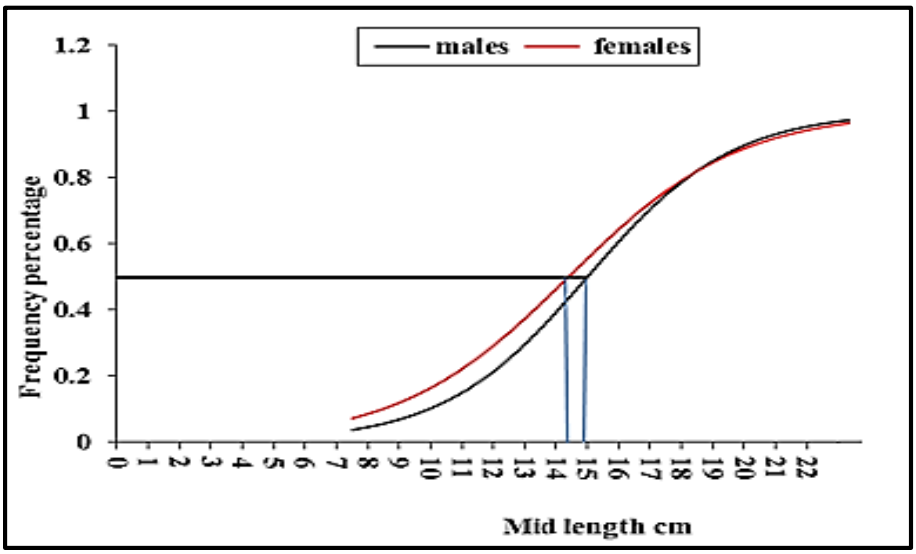

Fig.10. Size at first sexual maturity of *Pagellus erythrinus*, Mediterranean Sea, GSA 26.

15.08cm for males in the Aegean Sea (Eastern Mediterranean). Whereas, higher values were recorded for the same species in Portugal (17.29cm; Coelho et al. 2010), in the Tyrrhenian Sea (15.70cm for females and 17cm for males) (Busalacchi et al. 2014) and on the coast of Tunisia (15.32cm for combined sexes) (Ben Smida et al. 2014), a low value of 12.5 cm for females was observed in the Algerian western coasts (Mahdi et al. 2018). Lteif et al. (2020) gave a higher L_{50} value (16.38cm for sexes combined). These differences may be due to environmental factors and ecological conditions, such as temperature as well as the quality and quantity of food available (Metin et al. 2011). Furthermore, the eastern part of the Mediterranean is oligotrophic with much less food availability and has a higher temperature than the central and western parts (Azov 1991; Somarakis & Machias 2002). The decrease in biological production from west to east and from north to south in the Mediterranean is due to the increase in temperature and salinity in the same direction (Danovaro et al. 2008). This might have induced an early sexual maturity for the common pandora in GSA 26. In addition, overfishing on this species in the Egyptian Mediterranean can also be a reason for early maturation.

On the other hand, the length at first capture L_c (the length at which 50% of the fish at that size are vulnerable to capture) of the common pandora was estimated at 13.25 and 13.11cm for males and females respectively. It is obvious that the estimated Lc was lower than Lm for males and females. This means that the exploited *P. erythrinus* must be protected to share the spawning activities at least once before being caught.

Conclusion

The study of the reproductive dynamics of *P. erythrinus* revealed two facts that should be considered in its fisheries management in GSA 26. Firstly, the spawning period for the species extends from March to August which occurs during the active fishing season. Thus, it is necessary to reduce fishing pressure on this species during these times. Secondly, a considerable percentage of the catch comprises young fish that don't reach their sexual maturity and don't contribute in spawning. Accordingly, it is recommended to propose a closed season to protect *P. erythrinus* during its spawning season. Meanwhile, further studies on reproduction dynamics for other trawl fishes should be carried out. Outcome of such studies and the present work will be of great importance to determine the proper time for fishing and closing season. In addition, a detailed study concerned gear selectivity of trawl should be done to find the proper mesh size which conserve the stock of

P. erythrinus.

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مقاله کامل

پویایی سن، رشد و تولید مثل پاندورای معمولی، *Pagellus erythrinus* در GFCM-GSA 26 دریای مدیترانه، مصر

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چکیده: شانک ماهیان، از مهمترین ماهیان به‌واسطه داشتن ارزش اقتصادی بالا در آب‌های GFCM-GSA 26 دریای مدیترانه، مصر می‌باشند. آن‌ها حدود ۸ درصد از کل صید را تشکیل می‌دهند و حداقل از ۱۳ گونه را شامل می‌شوند که توسط ابزار صیادی متعدد مورد بهره‌برداری قرار می‌گیرند. پاندورا معمولی، *Pagellus erythrinus* در GSA26 یک گونه مهم با ارزش تجاری بالا بوده و گونه هدف صید های ترال است که در تمام فصل صیادی فعالیت می‌کند. تفاوت معنی‌داری بین سن و پارامترهای رشد جنس‌های نر و ماده وجود نداشت. سن از طریق خوانش کل اتولیت تعیین شد. سنین مشاهده شده در پنج گروه ۰ تا ۴ سال با طول‌های کل ۷ تا ۲۲/۹ سانتی متر را شامل می‌شدند. پارامترهای رشد ون برتالانفی برای داده‌های ترکیبی $L\infty$= ۲۶/۳۹ سانتی‌متر، k =۰/۳۴ $year^{-1}$ و t_0=۰/۷۹ سال بود. زیست‌شناسی تولیدمثلی *P. erythrinus* در GSA26 مورد بررسی قرار گرفت و شاخص‌های ماهانه گنادوسوماتیک و تغییرات در مراحل بلوغ نشان داد که *P. erythrinus* در بهار و تابستان از ماه مارس تا آگوست تخم‌ریزی بود. نسبت جنسی کل برای دوره‌های مطالعاتی به‌صورت ۱:۱/۲۹ برای جنس‌های نر وماده بود که تفاوت معنی‌دارای از مقادیر ۱:۱ داشت. اندازه در ۰/۵۰ بلوغ جنسی به‌ترتیب برای جنس‌های نر وماده ۱۴/۸ و ۱۴/۲در طول کل محاسبه شد. حدود ۴۰ درصد از *P. erythrinus* قبل از رسیدن به اولین بلوغ جنسی خود صید شدند که نشان می‌دهد در GSA26 حداقل طول مناسب فعلی برای مدیریت این گونه مناسب نیست. این مطالعه کاهش فشار صیادی به ویژه در طول فصل تخم‌ریزی و افزایش اندازه چشمه‌های توری مورد استفاده را توصیه می‌کند.

کلمات‌کلیدی: دریای مدیترانه، *Pagellus erythrinus*، تعیین سن، نسبت جنسی، فصل تخم‌ریزی.