Sexual maturity parameters of the Axillary seabream, *Pagellus acarne* (Risso, 1826) (Sparidae), in the Syrian marine waters

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□ ABSTRACT □

Axillary seabream, *Pagellus acarne* (Risso, 1826), represents an important component of the Syrian waters catch. This research was conducted on 1494 individuals that were collected from the Syrian waters; by local fishing methods (Gill nets, Trammel nets) between May 2019 until the end of April 2021. The overall sex ratio (M: F) was in favour of males (1.25:1), and length-frequency distribution according to sex revealed that the males predominated at the range (13.1-16) cm, while the females were highly representative beyond 16 cm total length; which confirmed a sexual inversion already described for this Protandry species. The sex inversion occurred at 15.6 cm of total length, and the length at first sexual maturity was 12.6 cm for males and 13.2 cm for females. Gonado-somatic index GSI(%) computation and morphological monitoring of gonads maturity revealed that the spawning period of *P. acarne* extends from October to the end of December.

Keywords: Axillary seabream, *Pagellus acarne*, Sparidae, Spawning season, Protandry, Syrian marine waters.

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مؤشرات النضج الجنسي عند أسماك السلمورة *Pagellus acarne* (Risso, 1826) (الأسبورات) في المياه البحرية السورية

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□ ملخّص □

تُعد أسماك السلمورة *Pagellus acarne* (Risso, 1826) مكوناً هاماً من مصيد المياه البحرية السورية. تم إجراء هذا البحث على 1494 فرداً من أسماك السلمورة التي جُمعت من المياه البحرية السورية باستخدام وسائل الصيد المحلية (الشباك المبطنة، الشباك الغلصمية)، خلال الفترة الممتدة بين شهر أيار عام 2019 وحتى نهاية شهر نيسان عام 2021. كانت نسبة الجنس الإجمالية 1:1.25 لصالح الذكور، وأظهر التوزع التكراري للأطوال تبعاً للجنس أن الذكور سيطرت ضمن مجال الأطوال (13.1–16) سم، بينما كانت الإناث ممثلة بدرجة عالية عند طول كلي أكبر من 16 سم، مما يؤكد انقلاب الجنس الذي تم وصفه مسبقاً لهذا النوع الخنثوي مبكر الذكورة. حدث انقلاب الجنس عند طول كلي 15.6 سم، وكان الطول عند أول نضج جنسي 12.6 سم للذكور و 13.2 سم للإناث. أظهر حساب معامل النضج الجنسي GSI(%) والدراسة الشكلية لنضج المناسل أن موسم التكاثر امتد من شهر تشرين الأول وحتى نهاية شهر كانون الأول.

الكلمات المفتاحية: السلمورة، *Pagellus acarne*، الأسبورات، موسم التكاثر، خنثوي مبكر الذكورة، المياه البحرية السورية.

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Introduction:

Axillary seabream, *Pagellus acarne* (Risso, 1826) is a sparid fish widely distributed throughout the eastern Atlantic (from Denmark to Senegal, and around the Madeira, Azores, Cape Verde and the Canary Islands), in the Mediterranean, and the Black sea (Bauchot and Hureau, 1986, 1990). It is a demersal species, inhabiting various types of sea bottoms, but is more common on sand and seagrass beds, the young are found closer to the shore (Bauchot and Hureau, 1986, 1990). *P. acarne* exhibits protandric hermaphroditism wherein most of the individuals first mature as males, with the immature ovarian zone adjoins; then they undergo testicular regression and the ovarian zone becomes functionally female (Le-Trong and Kompowski, 1972; Lamrini, 1986; Pajuelo and Lorenzo, 2000; Arculeo *et al.*, 2000).

Several international studies have been dealt with the biology of *P. acarne*, including the Mediterranean Sea, the western basin (Velasco *et al.*, 2011; Boufersaoui and Harchouche, 2015; Bentata-Keddar *et al.*, 2020), the central (Andaloro, 1982; Arculeo *et al.*, 2000; Di Maio *et al.*, 2020), and the eastern basin (Faltas, 1995; Mytilineou, 2000; Soykan *et al.*, 2015), also the northern Atlantic (Santos *et al.*, 1995; Coelho *et al.*, 2005), the eastern central Atlantic (Lamrini, 1986; Le-Trong and Kompowski, 1972), and the Canary Islands (Pajuelo and Lorenzo, 2000).

Pagellus acarne is one of the main target species of the commercial fishery in the Syrian marine waters, contributing approximately 7.2% of the total catch (Ulman *et al.*, 2015; Saad *et al.*,2016), and it is desirable to the local consumers. Despite its wide distribution and economic importance in the Syrian waters, data on the biology of *P. acarne* is completely lacking and no studies have been carried out on the biology of this species in the Syrian coast.

There were some studies on the sexual maturity and sex inversion in the Syrian waters that conducted on other species belongs to the Sparidae family (Saad *et al.*, 2014; Hammoud *et al.*, 2015; Alshawy, 2017, Ali-Basha, 2018).

The present research investigated some aspects of the reproductive biology of *P. acarne* off Syrian waters, including the sex ratio, reproduction season, sex reversal, sexual maturity stages, and size at first sexual maturity; to shed light on this basic information required for the good management of fishing of this species and increase opportunities to exploit its stock optimally.

Materials and methods:

Specimens of *P. acarne* were collected weekly from catch sites off the Lattakia governorate coasts, Syrian waters (Ras albasit, Lattakia, Jableh) (Figure 1,a); by various local fishing methods (Gill nets, Trammel nets) during the period from May 2019 until the end of April 2021, at depths up to 85 m, (Figure 1,b). A total of 1494 individuals were sampled. For each fish, total length (TL) and standard length (SL) were measured to the nearest mm, and total body weight (TW), eviscerated body weight (EW), gonad weight (GW), and liver weight (LW) were weighed to the nearest 0.01 g. The sex of individuals was ascertained macroscopically and recorded for each fish sampled. Fish having only male or female gonads were determined to be male or female, and fish having both gonads (gonotestis) were determined to be hermaphrodites, and the stages of sexual maturity were classified based on the gonadal development criteria described by Holden and Raitt (1974): I- Immature, II- Maturing virgin and recovering spent, III- Ripening, IV- Ripe, V- Spent.

The gonads were preserved in 10% buffered formalin. The percentages of males, females, hermaphrodites, Juveniles and the overall ratio of males to females were estimated.
The monthly evolution of the Gonado-somatic index GSI (%), Hepato-somatic index HSI (%) and Condition factor CF (%) were calculated as:
GSI= GW / EW * 100 (Bagenal, 1978)
HSI= LW / EW * 100 (Pravdin, 1966)
CF= EW / L^3 * 100 (Pravdin, 1966)
Where GW is the gonad weight, LW is the liver weight, EW is the eviscerated body weight, and L is the total body length. The eviscerated body weight was used instead of total body weight to avoid errors from changes in digestive system content and gonad weight throughout the year.
The size at first sexual maturity was defined as the total length at which 50% +1 of the fish had become mature, and was determined as the size class at which 50% +1 of individuals are mature after grouping the individuals into 0.5 cm size classes and the proportion of mature and immature individuals were recorded in each class (Gunderson,1977).

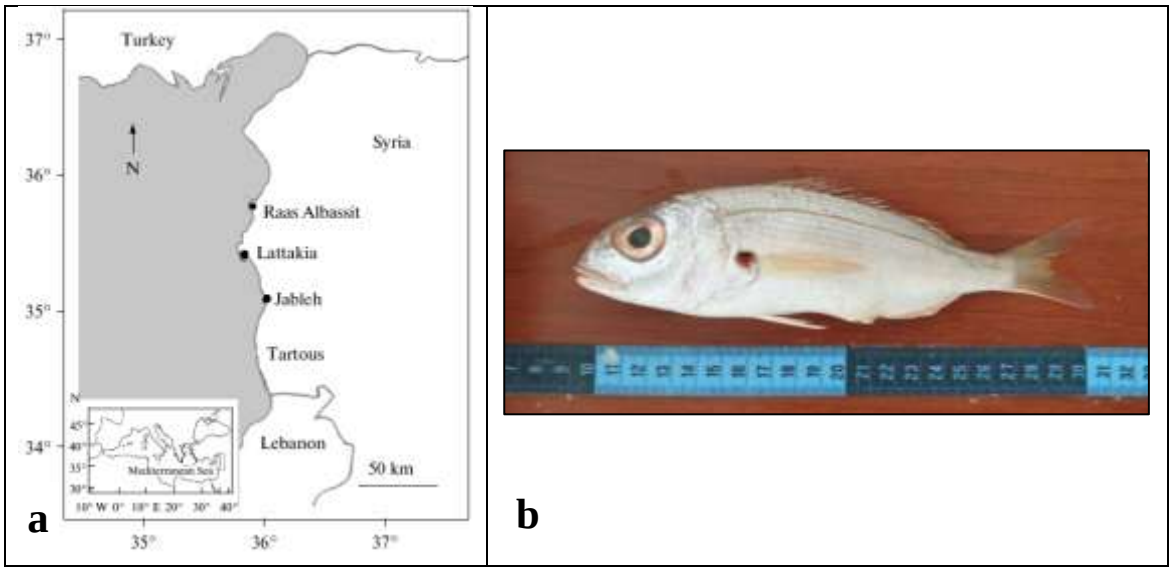


Figure (1): a- sites of sampling area, b- *P. acarne*, female (TL: 21.6 cm, TW: 123.4 g) was caught from Lattakia.

Results:

In total, 1494 individuals of *P. acarne* were collected, 582 (39%) males, 465 (31.1%) females, 172 (11.5%) hermaphrodites, and 275 (18.4%) Juveniles. Morphometric and weight measurements of specimens are summarized in table (1), and the length-frequency distribution of the entire population is shown in figure (2). A high percentage of individuals smaller than 13 cm were juveniles. Males presented in the range (11.1-18) cm, and were dominant between (13.1-16) cm, while females showed in the range (12.1-22) cm, and were dominant at sizes above 16 cm. The overall ratio of males to females (M: F) was 1.25:1 in favour of males, and Chi-square analysis revealed that there were statistically significant differences between males and females ($\chi^2 = 13.074$, $p < 0.05$). Hermaphrodites were present in the range (13.1-18) cm, and the size at sex inversion took place at 15.6 cm.
The size at first sexual maturity:

The smallest sexually mature individual was 12.2 cm for males; and 12.7 cm for females, while the size at first sexual maturity was estimated at 12.6 cm for males, and 13.2 cm for females; which 50% +1 of males and females in the population reached sexual maturity, and all individuals were sexually mature at length above (13.5, 14) cm for males and females, respectively, (Figure 3).

Table (1): Length (cm) and weight (g) measurements of *P. acarne* individuals.

	TL (cm)		TW (g)		n
	Range	M ± SD	Range	M ± SD	
Juveniles	10 - 13.2	12 ± 0.6	13.5 - 29.4	20.4 ± 3.5	275
Females	12.2 – 21.6	15.5 ± 1.6	19.6 - 123.4	48.6 ± 17.3	465
Males	11.6 - 17.6	14.6 ± 1.4	16.8 - 68.8	39.6 ± 12.4	582
Hermaphrodites	13.2 - 17.3	15.6 ± 1.2	29 - 66	48.6 ± 10.6	172

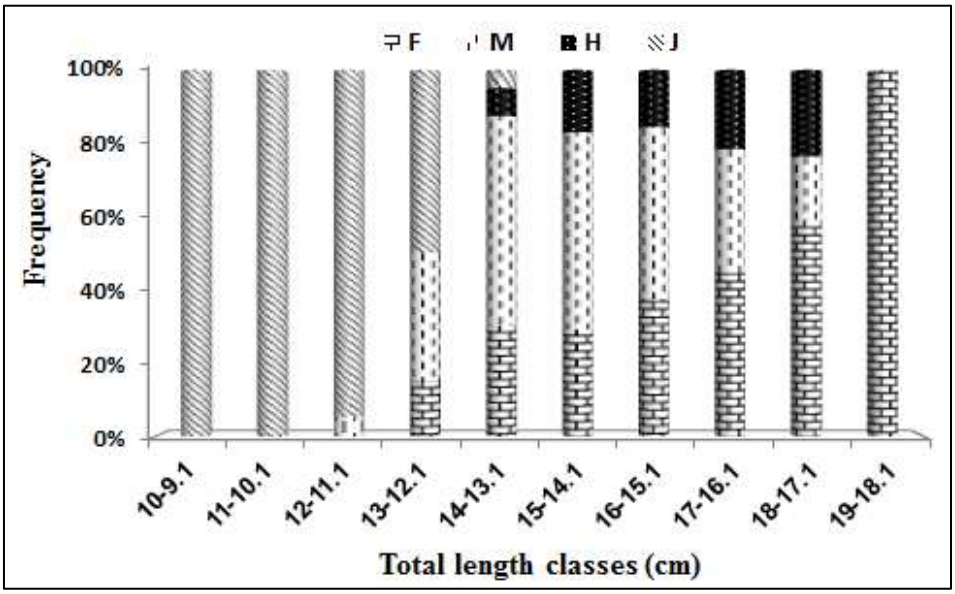


Figure (2): The length frequency distribution of *P. acarne* individuals.

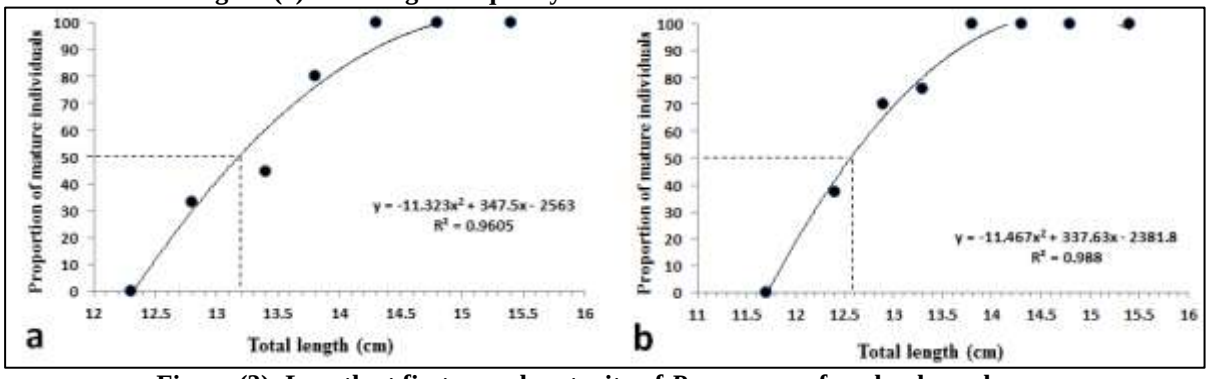


Figure (3): Length at first sexual maturity of *P. acarne*. a- females, b- males.

Maturity stages:

Based on the macroscopic observations of the gonads and their maturity degree, the gonads were classified into five stages according to Holden and Raitt (1974):

I- Immature: Ovary and testis about 1/3 length of a body cavity. Ovaries are pinkish and translucent; testis whitish (Figure 4,5-a). Wherein this stage is observed during most months of the year in varying proportions, and its highest percentage was during July (Figure 6).

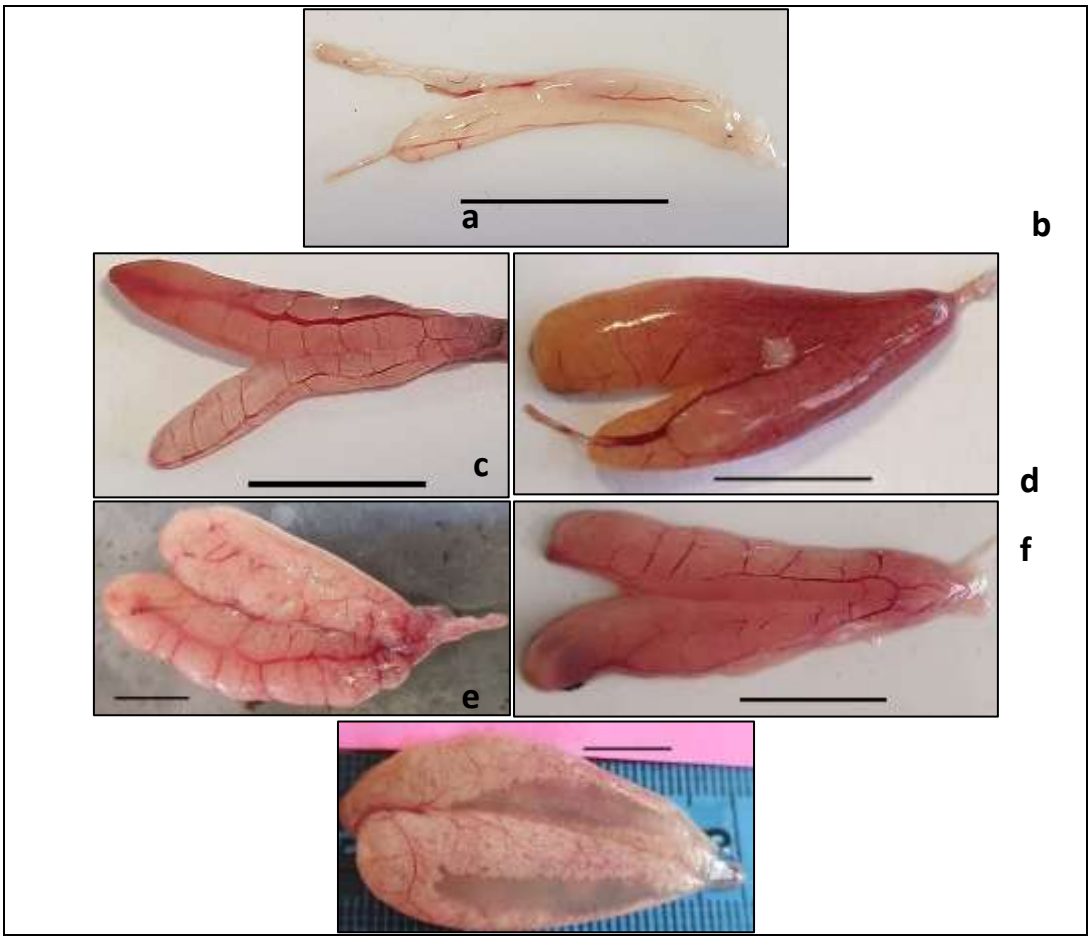


Figure (4): Maturity stages of ovaries. a- Immature stage, b- Maturing virgin stage, c- Ripening stage, d- Ripe stage, e- Spent stage, f- the onset of spent stage. Scale bar= 1 cm.

II- Maturing virgin and recovering spent: ovary and testis about 1/2 length of a body cavity. Ovary pinkish and translucent; testis whitish and more or less symmetrical. Eggs are not visible to the naked eye (Figure 4,5-b). This stage extended throughout the year and was prevalent in February (Figure 6).

III- Ripening: ovary and testis about 2/3 length of a body cavity. Ovary pinkish-yellow colour with granular appearance; testis whitish to creamy in colour. No transparent or translucent eggs visible (Figure 4,5-c). This stage dominated during October (Figure 6).

IV- Ripe: ovary and testis from 2/3 to a full length of a body cavity. Ovary orange-pink in colour with conspicuous superficial blood vessels. Large transparent ripe eggs are visible. Testis whitish- creamy in colour and soft (Figure 4,5-d). This stage extended from October to December and dominated in November (Figure 6).

V- Spent: ovary and testis shrunken to about 1/2 length of a body cavity. Walls lose. The Ovary may contain remnants of disintegrating opaque and ripe eggs, darkened or translucent. The testis is bloodshot and flabby (Figure 4,5-e). This stage presented in November and December with a clear predominance during December (Figure 6).

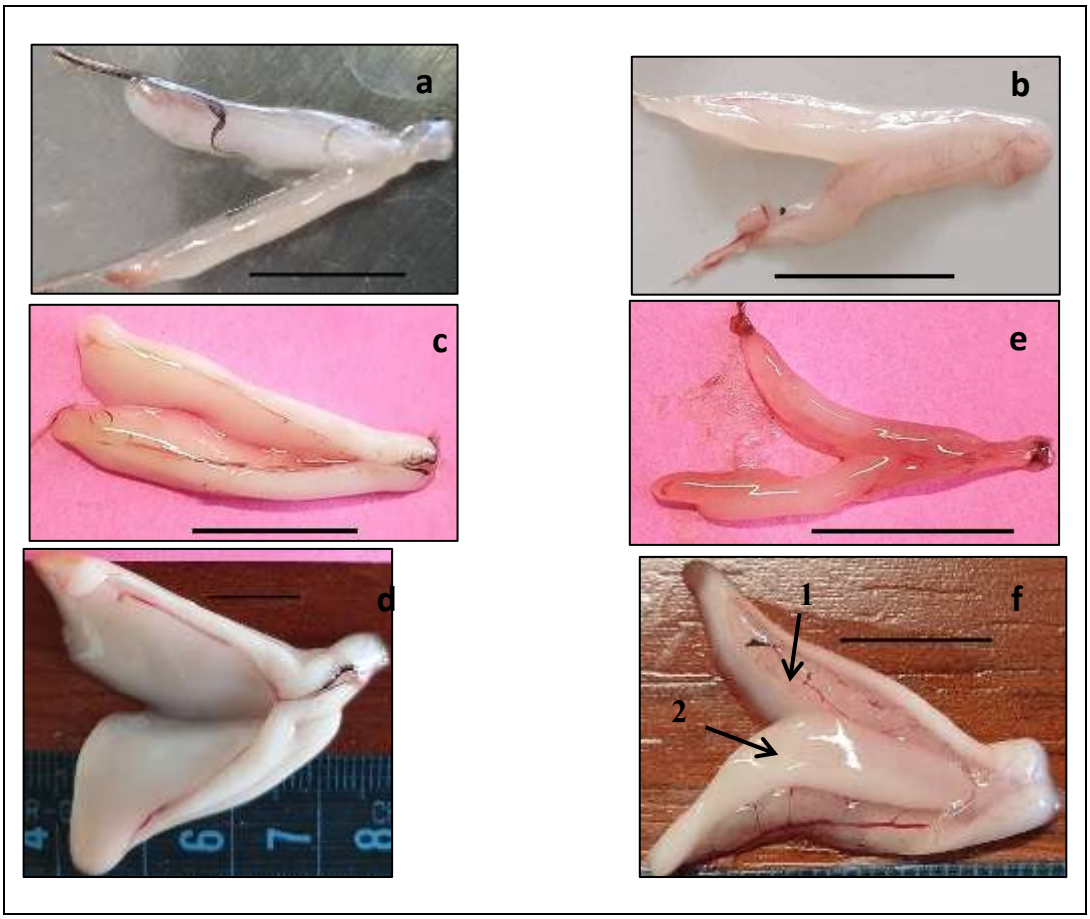


Figure (5): Maturity stages of testes. a- Immature stage, b- Maturing virgin stage, c- Ripening stage, d- Ripe stage, e- Spent stage, f- testis at sex reversal (1- ovarian section, 2- testicular section). Scale bar= 1cm.

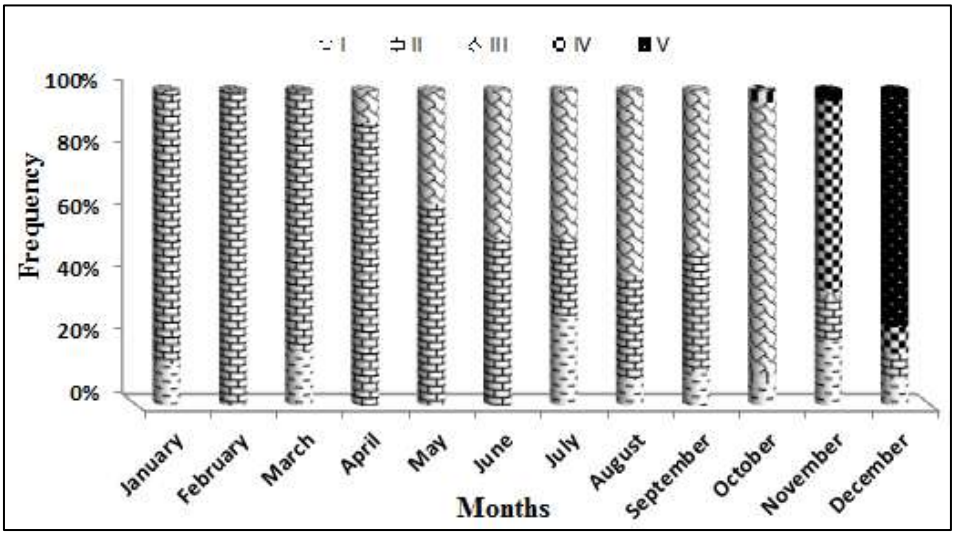


Figure (6): Monthly variations of the frequency of gonads development stages.

Gonado-somatic index GSI (%):

The Gonado-somatic index GSI (%) was used to determine the reproductive period, which was calculated from samples taken monthly. The results showed that the value of GSI (%) began to increase significantly during October for both years of the study, reaching its value for females (1.21 ± 0.28, 1.38 ± 0.31) with an average weight of the ovaries (0.6 ±

0.14, 0.63 ± 0.23) g and males (1.04 ± 0.27, 1.66 ± 0.63) with an average testes weight (0.52 ± 0.14, 0.74 ± 0.3) g. Most of the gonads during this month were in the stage of maturity III. The value of GSI (%) continued to increase to record its highest value during November for both years of the study, reaching its value for females (5.39 ± 1.55, 6.27 ± 1.66) with an average weight of the ovaries (2.79 ± 0.73, 3.5 ± 1.2) g and males (4.45 ± 1.11, 4.89 ± 0.96) with an average weight of the testes (1.94 ± 0.71, 2.2 ± 0.57) g. Most of the gonads during this month were in the IV maturation stage. Followed by a significant decrease in the GSI (%) value during December for both years of the study, which amounted to (0.43 ± 0.04, 0.34 ± 0.10) for females with an average weight of the ovaries (0.11 ± 0.04, 0.09 ± 0.03) g and (0.45 ± 0.18, 0.33 ± 0.05) for males with an average testes weight (0.13 ± 0.04, 0.08 ± 0.02) g, wherein most of the ovaries were at the V stage (Figure 7,8- a,b).

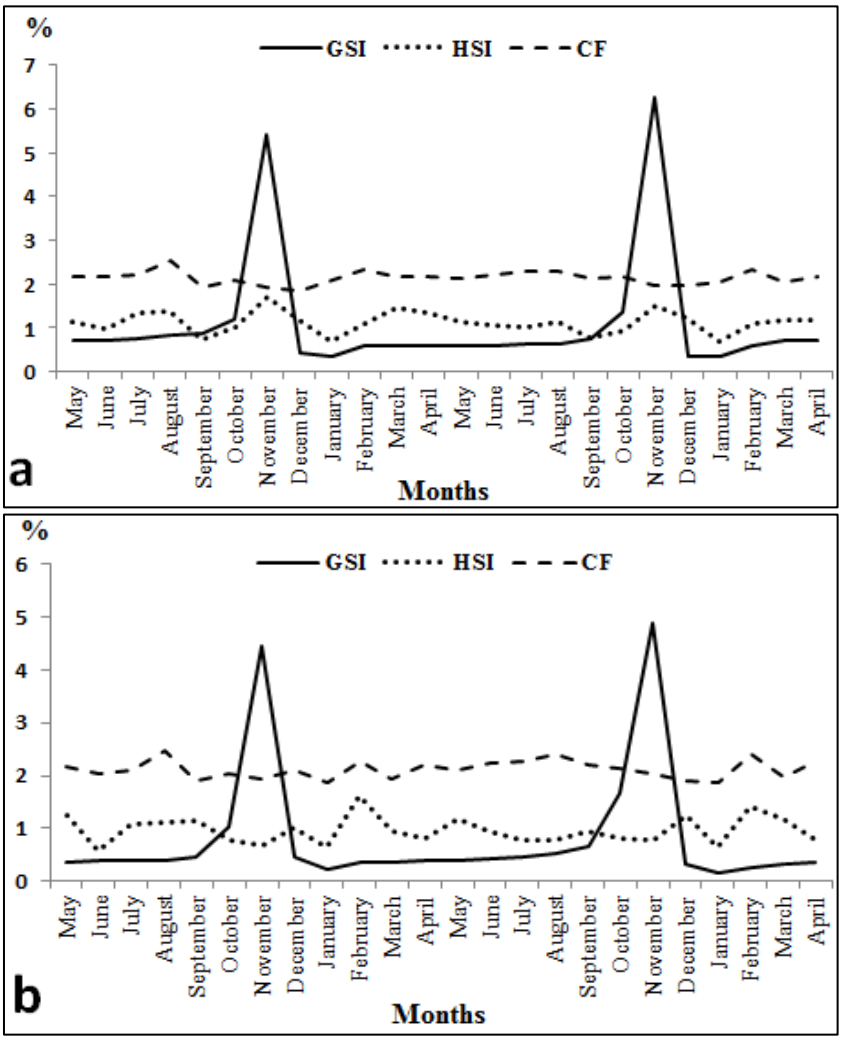
Hepato-somatic index HSI (%):

The HSI (%) values varied throughout the year for both females and males. For females, the values of HSI (%) coincided with the values of GSI (%) during the spawning period, wherein the highest HSI (%) values were during November for both years of the study (1.68 ± 0.41, 1.5 ± 0.4), with an average liver weight (0.87 ± 0.17, 0.79 ± 0.43) g. While the lowest HSI (%) values were during January for both years of the study, as it was (0.7 ± 0.19, 0.68 ± 0.13) with the average weight of the liver (0.24 ± 0.06, 0.25 ± 0.05) g, then the HSI (%) values returned to increase during the spring and summer months (Figure 7,8- a).

As for males; the HSI (%) values were contrary to those of the GSI (%) during the spawning period. The HSI (%) values decreased to reach their lowest value during November for both years of the study (0.68 ± 0.27, 0.79 ± 0.23) with the average weight of the liver (0.26 ± 0.12, 0.26 ± 0.11) g, and the highest HSI (%) values were (1.63 ± 0.29, 1.4 ± 0.51) during February for both years of the study with an average liver weight (0.8 ± 0.21, 0.78 ± 0.23) g (Figure 7,8- b).

Condition factor CF (%):

There were no clear monthly changes in the value of CF (%) during the study period, but the values fluctuated up and down. For both years of the study, the highest values of CF (%) were reached during August (2.55 ± 0.07, 2.3 ± 0.17) for females and (2.47 ± 0.1, 2.4 ± 0.07) for males. Whereas, the lowest values of CF (%) for females were during December (1.86 ± 0.09, 1.95 ± 0.07) and for males during January (1.89 ± 0.2, 1.86 ± 0.23) (Figure 7- a,b).



Figure(7): Monthly variations of GSI, HSI, CF. a- females, b- males.

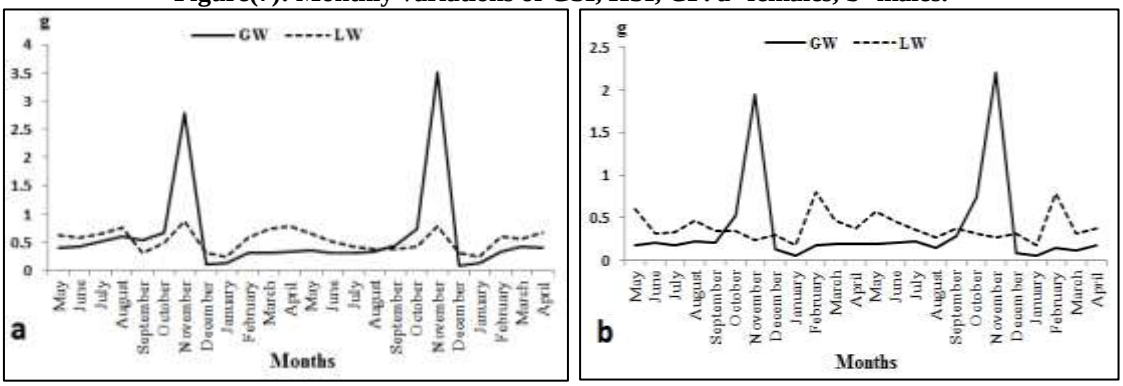


Figure (8): Monthly variations on average of gonads weight (GW) and Liver weight (LW) of *P. acarne*. a- females, b- males.

Discussion:

This study showed that the axillary seabream, *P. acarne* had one short spawning season that extends from October to the end of December with a clear peak in November for both females and males, where the peaks of GSI coincided with the spawning period as determined by the study of maturity stages. By comparing the spawning period in our

study with previous studies conducted on *P. acarne*, the same result was observed by Faltas (1995) in Egypt, whereas the other studies revealed that this species had one long spawning season that extends from May to October in south Spain (Velasco *et al.,* 2011) and from May to November (Coelho *et al.,* 2005) in Portugal. In the western Mediterranean, the spawning season of *P. acarne* take place in summer (Andaloro, 1982; Arculeo *et al.,* 2000) in Italy, and from late spring to autumn in Algeria (Bentata-Keddar *et al.,* 2020). Whilst, in Morocco, the reproduction occurs in summer (Lamrini, 1986), and from October to March in Canaries archipelago (Pajuelo and Lorenzo, 2000) (Table 2). This species tends to spawn between winter and spring in lower latitudes and later during the rest of the year in higher latitudes, that already been described by (Pajuelo and Lorenzo, 2000). On the other hand, some authors (Wootton, 1979; Pajuelo and Lorenzo, 2000; Mouine *et al.,* 2007) link these differences in time and duration of the spawning process with many factors such as temperatures and food availability in the different studies regions, where Gonçalves and Erzini (2000) confirmed that the reproduction period is much longer when environmental conditions are favourable.

For the length at first sexual maturity of *P. acarne* in the Syrian waters, it occurs at (12.6, 13.2) cm for males and females, respectively. Where males attain sexual maturity at a smaller size than females, the same result was observed by (Santos *et al.,* 1995; Pajuelo and Lorenzo, 2000; Velasco *et al.,* 2011; Soykan *et al.,* 2015; Bentata-Keddar *et al.,* 2020). Also, the studies on *P. acarne* in the Mediterranean sea (Andaloro, 1982; Velasco *et al.,* 2011; Boufersaoui and Harchouche, 2015; Soykan *et al.,* 2015; Bentata-Keddar *et al.,* 2020) and the present study report smaller sizes at first sexual maturity compared to results that obtained in the Atlantic ocean (Lamrini, 1986; Santos *et al.,* 1995; Pajuelo and Lorenzo, 2000; Coelho *et al.,* 2005; Velasco *et al.,* 2011). These differences can be explained by the Mediterranean water being warmer than Atlantic water; as the temperature is an important factor that influences sexual activity, that already described by Bentata-Keddar *et al.* (2020), besides the effect of sampling biases resulting from the different fishing methods that used in each study (Ali-Basha, 2018).

By following the changes in HSI (%) values and comparing them with GSI (%) values, the values of HSI (%) coincided with the values of GSI (%) during the spawning period for females, whereas the HSI (%) values for males were contrary to those of the GSI (%) during the spawning period, this result indicates that the males depend on the liver lipids reserves for its sexual activity, unlike females which seems to be channelled its liver lipids reserves to muscular activity.

Moreover, the condition factor of *P. acarne* in this study seems to be affected in its activity, where its values decreased during cold months and increased during hot months; for males and females, this confirms the use of lipids reserves in the muscles in its activity.

The overall sex ratio (M: F) in our study was unbalanced in favour of males because males were caught more than females, this result has also been observed for this species in Italy (Arculeo *et al.,* 2000), in Algerian waters (Bentata-Keddar *et al.,* 2020), and Spain (Velasco *et al.,* 2011). In contrast, the sex ratio in other studies is in favour of females (Pajuelo and Lorenzo, 2000; Boufersaoui and Harchouche, 2015).

The predominance of females in larger length classes and males in smaller length classes is probably due to protandric hermaphroditism, that what we observed during our study, where the macroscopic study of the gonads showed the presence of hermaphroditic gonads (containing an advanced ovarian section and a regressive testicular section), (Figure 5-f); and this could be owing to many factors such as behavioral factors (demographic) or

environmental factors (temperature, nutrition), rather than genetic factors (Ali-Basha, 2018). The protandry has also pointed out in studies that dealt with the sexuality of *P. acarne* (Lamrini, 1986; Arculeo *et al.*, 2000; Pajuelo and Lorenzo, 2000; Coelho *et al.*, 2005; Boufersaoui and Harchouche, 2015; Bentata-Keddar *et al.*, 2020).

Conclusions and Recommendations:

The Axillary seabream, *P. acarne* constitutes an important commercial species in the Syrian marine waters. It is a protandric sparid fish, spawns in the autumn, and reaches its sexual maturity at total length (12.6, 13.2) cm for males and females, respectively. Although there is a closed period for fishing in Syria at spring, we suggest to allocating a second closed period at autumn for species that spawns in this times of the year to protect these species and allow brooder fish to complete the reproductive process. By doing so, individuals of *P. acarne* whose its total length is less than 12 cm; can be allowed to grow and reproduce at least once in its life, and enhancing regeneration of its stock.

Table (2): Spawning period, length at first sexual maturity(cm), and sex ratio from different locations of *P. acarne*.

Author	Location	Spawning period	Length at first sexual maturity (cm)		**Sex ratio M:F**
			m	f	
Andaloro, 1982	Mediterranean (Italy)	July to September	16.5		
Lamrini, 1986	Atlantic (Morocco)	summer	20.9		
Santos *et al.*, 1995	Atlantic (Portugal)	May to August	19.7	20.95	
Faltas, 1995	Mediterranean (Egypt)	October to December			
Arculeo *et al.*, 2000	Mediterranean (Italy)	summer			2.1:1
Pajuelo and Lorenzo, 2000	Atlantic (Canarias archipelago)	October to March	15.8	19.4	1:1.74
Coelho et al., 2005	Atlantic (Portugal)	May to November	18.1	17.6	
Velasco *et al.*, 2011	Atlantic (Spain)	May to October	18.04	21.7	1.7:1
	Mediterranean (Spain)		17.7	20.1	2:1
Boufersaoui and Harchouche, 2015	Mediterranean (Algeria)	March to June	16.8	16.45	1:1.5
Soykan *et al.*, 2015	Mediterranean (Turkey)		13.91	14.45	
Bentata-Keddar *et al.*, 2020	Mediterranean (Algeria)	Late spring and autumn	16.95	18.63	1.56:1
Present study	Mediterranean (Syria)	October to December	12.6	13.2	1.25:1

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