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Age, growth, Mortality and Exploitation of the Axillary seabream, *Pagellus acarne* (Risso, 1826) (Sparidae) from the Syrian marine waters

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Abstract:

The Axillary seabream, *Pagellus acarne* is considered as one of the main target species of the commercial fishery in the Syrian marine waters, and there is no study yet on its biology in the Syrian coast. As the growth biology is of great importance in the good management of fishing of this species and increases opportunities to optimally exploit its stock. A total of 1494 individuals of *P. acarne* were collected from the Syrian coast between May 2019 and April 2021. The age composition consisted of five age groups. The length-weight relationship revealed a positive Allometric growth (b= 3.292, 3.263, 3.29) for all population, males and females, respectively. The Von Bertalanffy growth parameters and growth performance index φ` were calculated: $L_\infty$= 19.78 cm, 21.5 cm and 22.97 cm; K= 0.23, 0.32 and 0.18; $t_0$= -0.044 years, -0.238 years and -0.239 years; $\varphi_L$`= 1.95, 2.17 and 1.97 for all population, males and females, respectively. The resilience / productivity of *P. acarne* was medium ($0.16 \leq K < 0.30$), and depending on the concept of maximum age T_{max} (13 years), it has low value (T_{max} = 11 – 30 years). The age and length at first capture and recruitment were: T_c= 1.78 years, T_r= 1.07 years, L_c= 6.78 cm and L_r= 4.48 cm. The total and natural mortality, survival and exploitation rates were: Z= 0.92 $year^{-1}$, M= 0.703 $year^{-1}$, S= 0.4 $year^{-1}$ and E= 0.14 $year^{-1}$.

Keywords: Axillary Seabream, *Pagellus Acarne*, Growth, Mortality, Survival, Exploitation.

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العمر، والنمو، والنفوق والاستغلال عند أسماك السلمورة *Pagellus acarne* (Risso,1826) من عائلة الأسبورات (Sparidae) في المياه البحرية السورية

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الملخص:

تعتبر السلمورة *Pagellus acarne* أحد الأنواع السمكية المستهدفة في المصيد التجاري في المياه البحرية السورية، ولا توجد أي دراسة بعد حول بيولوجيا هذا النوع في الساحل السوري. حيث أن بيولوجيا النمو ذات أهمية كبيرة في الإدارة الجيدة لصيد هذا النوع وزيادة فرص استغلال مخزونه بالشكل الأمثل. تم جمع 1494 فرداً من أسماك السلمورة من الساحل السوري خلال الفترة الممتدة بين شهر أيار 2019 وشهر نيسان 2021. أظهر التركيب العمري تشكل خمس فئات عمرية. أظهرت علاقة الطول بالوزن نمواً غير متجانساً إيجابياً (b= 3.292، 3.263، 3.29) لجميع الأفراد، والذكور والإناث على التوالي. تم حساب معاملات برتلانفي للنمو ودليل كفاءة النمو φ' حيث كانت: L_∞= 19.78 سم، 21.5 سم سنة؛ φ_L'= 1.95، 2.17 و1.97 لجميع الأفراد، والذكور والإناث على التوالي. أبدت السلمورة مرونة / إنتاجية متوسطة ($0.30 > K \geq 0.16$)، واعتماداً على العمر الأقصى T_{max} (13 سنة) أبدى هذا النوع مرونة / إنتاجية منخفضة (T_{max}= 11–30 سنة). كان العمر والطول عند أول صيد وعند الإمداد T_c= 1.78 سنة، T_r= 1.07سنة، L_c= 6.78 سم و L_r= 4.48 سم. بلغ النفوق الكلي والطبيعي ومعدلات البقاء والاستغلال Z= 0.92 سنة$^{-1}$، M= 0.703 سنة$^{-1}$، S= 0.40 سنة$^{-1}$ و E= 0.14 سنة$^{-1}$.

الكلمات المفتاحية: السلمورة، *Pagellus acarne*، النمو، النفوق، البقاء، الاستغلال.

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Introduction:

Axillary seabream, *Pagellus acarne* (Risso, 1826) is a member of Sparidae family and Perciformes order. It is a demersal species, inhabiting various types of sea bottoms, but it is more common on sand and seagrass beds, the young are found closer to the shore (Bauchot & Hureau, 1986; 1990). It 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 & Hureau, 1986; 1990). *Pagellus 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 & Kompowski, 1972; Lamrini, 1986; Pajuelo & Lorenzo, 2000; Arculeo *et al*., 2000).

There are many international studies that have been conduct on the biology of *P. acarne* (Le-Trong & Kompowski, 1972; Lamrini, 1986; Faltas, 1995; Santos *et al.*, 1995; Mytilineou, 2000; Arculeo *et al.*, 2000; Boufersaoui & Harchouche, 2015), and studies on its growth in Italy (Andaloro, 1982), Morocco (Mennes, 1985), Canaries islands (Pajuelo & Lorenzo, 2000), Portugal (Coelho *et al.*, 2005), Spain (Velasco *et al*., 2011), Turkey (Soykan *et al*., 2015; Ilhan, 2018), and Algeria (Bentata-Keddar *et al*., 2020).

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

The present research investigated in the growth biology of *P. acarne* off Syrian waters, including the age, growth, mortality, exploitation, and survival; 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:

This research has been carried out on /1494/ individuals of *Pagellus acarne*, collected weekly from catch landing ports off the Lattakia governorate coasts, Syrian waters (Ras albasit 35° 50′ N 35° 50′ E, Lattakia 35° 31′ N 35° 47′ E , Jableh 35° 22′ N 35° 55′ E); at depths up to 85m, by various local fishing methods (Gill nets, Trammel nets) during the period from May 2019 to the end of April 2021. For each fish, sex, total length TL (cm), standard length SL (cm), total and eviscerated body weight (g) were recorded.

Age determination and back- calculations:

Scales were removed from between the first ray of the dorsal fin and the lateral line, cleaned and viewed with low-power microscope (16X). Scale radius and distance from focus to each ring were measured with an ocular micrometer. Mean values of scale radius were calculated for each 1 cm length group. The scale radius and total length relationship was determined by the least square method. Correction for back calculated fish length-at-each year of life was calculated by Lee formula:

$$\mathbf{L_n = S_n\,(TL - a) / S + a}$$

Where: L_n is the length (cm) at age 'n', TL is the total length (cm), S_n is the radius of annulus 'n', S is the scale radius and a is the intercept of the regression line. Mean observed length-at-age and back-calculated lengths were computed.

Length-weight relationship:

Length-weight relationships were determined using the formula: $\mathbf{TW = aTL^b}$

Where: TW is the total weight (g), TL is the total length (cm), b is the length-weight factor and a is a constant.

Von Bertalanffy growth model

The von Bertalanffy growth model was chosen to back-calculated length-at-age and describe the growth of *P. acarne*, depending on the Akaike information criterion (AIC) [AIC= N ln (WSS) + 2M (Akaike, 1974)] in the comparison between the available growth models that describe the growth of the fish species (Hamwi, 2018). Where N is the number of data points, WSS is the weighted sum of squares of residuals and M is the number of model parameters.

The model was of the form**: $L_t = L_\infty / [1+ e^{-k (t-t0)}]$**

Where: L_t is the length (cm) at time t (years), L_∞ is the asymptotic length (cm), K is the growth coefficient and t_0 is the theoretical age at birth.

Growth performance index:

In order to compare different estimations of growth parameters, the empirical equation of growth performance ($\varphi_L` = \mathbf{logk + 2logL_\infty}$) of Pauly and Munro (1984) was used. In addition, maximum Age (T_{max}) and maximum length (L_{max}) were estimated as:

$\mathbf{T_{max} = 3 / k + t_0}$ (Pauly, 1983)

$\mathbf{\log L_\infty = 0.044 + 0.9841 \log L_{max}}$ (Froese & Pauly, 2000)

Mortality and exploitation rates:

The total instantaneous mortality rate (Z) was calculated from the catch curve as described in Ricker (1975).

Natural mortality rate (M) was estimated from the equation of Pauly (1980) as:

$\mathbf{\log M = -0.0066 – 0.279 \log L_\infty + 0.6543 \log K + 0.4634 \log T}$

where: L_∞ and K are the parameters of the Von Bertalanffy Growth Model and T is the annual mean sea surface temperature of the fishing area, here set at T = 23.2 C°.

The difference between total mortality rate (Z) and the natural mortality rate (M) gives an estimate of fishing mortality (F): $\mathbf{F = Z - M}$

Survival ratio (S) was estimated from the equation (Ricker, 1975): $\mathbf{S = e^{-z}}$

According to Cushing (1968), the ratio of exploitation (E) is: $\mathbf{E = F*A / Z}$

Where: F and Z are fishing and total mortalities and A is the annual mortality rate (A = 1 – S).

Length at first capture and recruitment

Length at first capture (L_c) and length at recruitment (L_r) were determined using Beverton and Holt (1957) equations:

$\mathbf{L_c = L' - [K (L_\infty - L') / Z]}$ $\mathbf{L_r = L' - [K (L_\infty - L_0) / Z]}$

Where: L' is the mean length of fish in the catch sample, K and L_∞ are parameters of the Von Bertalanffy growth equation and Z is the instantaneous mortality rate.

The corresponding age at first capture (T_c) and age at recruitment (T_r) were calculated as:

$\mathbf{T_c = - (1 / K) * \ln (1 - L_c / L_\infty) + t_0}$ $\mathbf{T_r = - (1/K) * \ln (1 - L_r / L_\infty) + t_0}$

The statistical programs SPSS and Excel were used to process the data we obtained, and we used the following tests to compare the different averages: ANCOVA test, Student's T-Test, and Chi-square test χ^2, at a significant difference (*P*) 0.05.

Results and Discussion:

In total, 1494 individuals of *Pagellus acarne* were collected, 582 (39%) males, 465 (31.1%) females, 172 (11.5%) hermaphrodites, and 275 (18.4%) Juveniles. The relative frequency of the total length categories (TL), varied between 10 cm and 21.6 cm, individuals with lengths (13.1-14) cm were the most abundant by (21.22%) (Figure 1). The Axillary seabream was represented by five age groups, as the most abundant was the age group III (30.99%), while the age group V was the least abundant (4.89%) (Figure 2).

Table (1): Age and size of *P. acarne* from different areas.

Author	Locality	Age (year)	Total length (cm)
Pajuelo & Lorenzo, 2000	Canaries Islands	10	31
Coelho *et al.*, 2005	Portugal	13	30
Velasco *et al.*, 2011	Alboran sea	7	29.4
	Gulf of Cadiz	7	28.2
Ilhan, 2018	Gulf of Izmir	4	22
Bentata-Keddar *et al.*, 2020	Algeria	4^+	26.2
Present study	Syria	5^+	21.6

The largest total length (TL) of *P. acarne* caught from the Syrian waters was 21.6 cm at the age of 5^+, whilst the smallest total length of the individuals was 10 cm at the age of 1^+, while the oldest individual of *P. acarne* that given in the other studies ranged between 4 to 13 years at total lengths varied from 22 to 31 cm (Table 1).

The overall ratio of males to females (M: F) was 1.25:1 in favour of males, and Chi-square analysis reveals that there were statistically significant differences between males and females ($\chi^2 = 13.074$, $P \leq 0.05$). Males were dominant in the second II and third III age groups, while the females were dominant in the fourth IV and fifth V age groups. All individuals in the first I age group were Juveniles, and the hermaphrodites were present in the III and IV age groups (Figure 3). The study pointed out that the individuals are mainly males in the earlier years of life and females in the later ones; as well as the presence of hermaphrodites, which is owing to the protandric hermaphrodite that characterizes this species and had been previously described for this species (Alekssev, 1967; Pajuelo & Lorenzo, 2000; Coelho *et al.*, 2005).

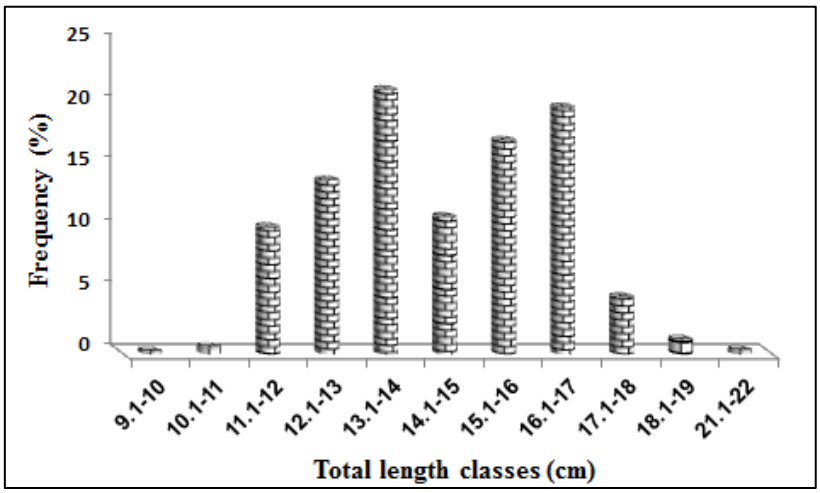

Fig. (1):Total length-frequency distribution of *P. acarne* in the Syrian coast.

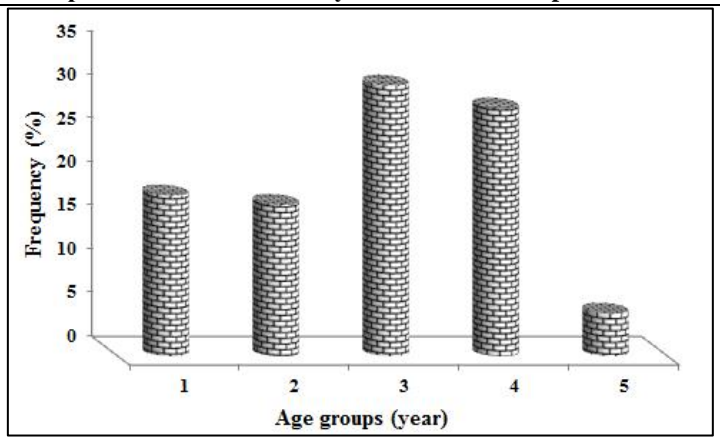

Fig. 2. Age composition of *P. acarne* in the Syrian coast.

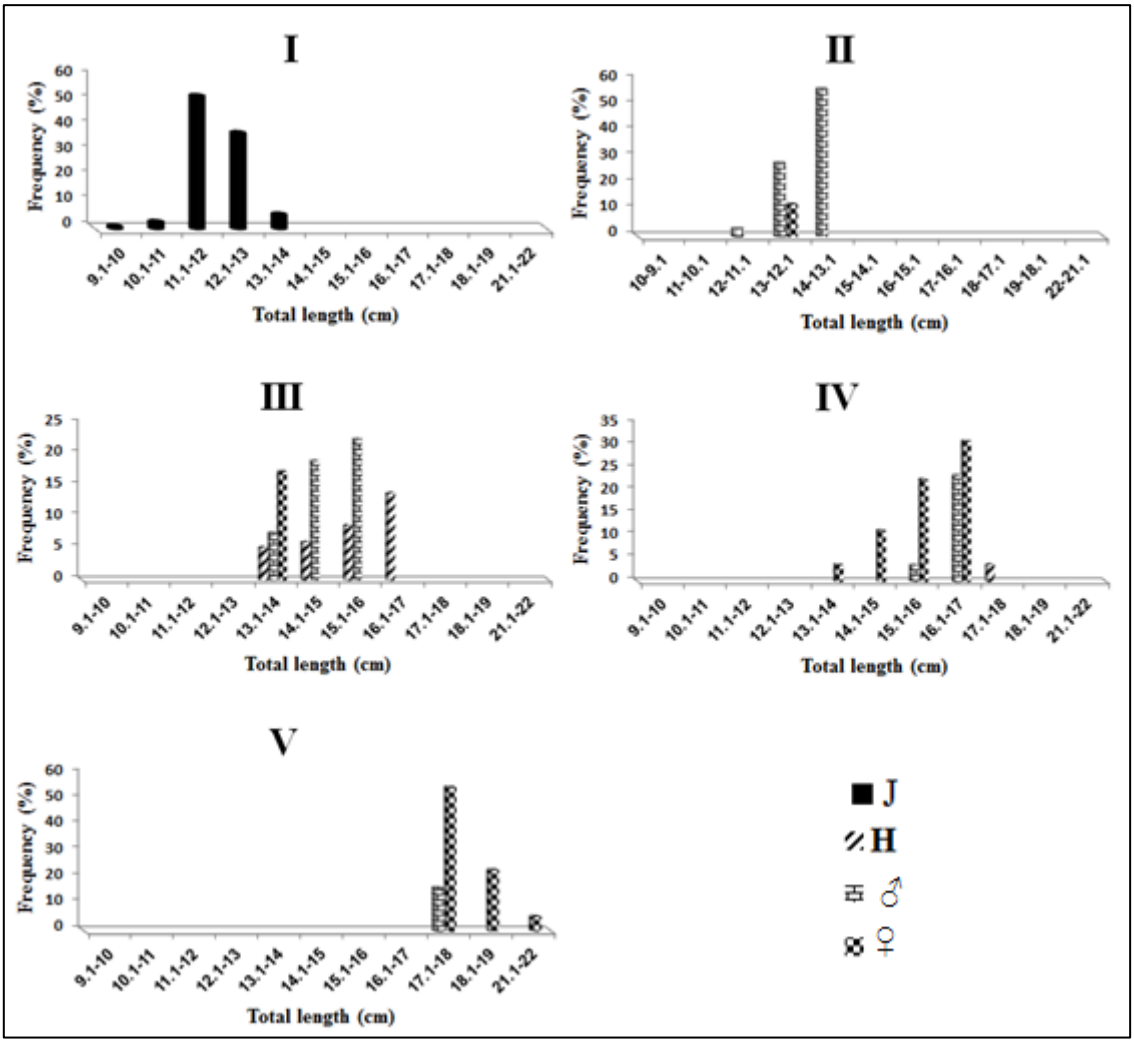

Fig. 3. Age, Size and sexual composition of *P. acarne* from Syrian coast. (I, II, III, IV, V) age groups, ♂- males, ♀- females, H- hermaphrodites and J- juveniles.

Table (2): Average of total length by the back-calculation. t- absolute annual linear increment, All- all population, ♂- males, ♀- females, n- Number of individuals.

		Length at each age-group					
		TL_1	TL_2	TL_3	TL_4	TL_5	n
Average of total length (TL, cm)	**All**	4.56±0.018	6.48±0.019	10.35±0.013	12.59±0.012	13.11±0.022	1494
	♂	6.95±0.10	11.33±0.02	14.02±0.01	15.42±0.07	17.86±0.02	582
	♀	4.77±0.04	6.80±0.02	10.15±0.025	12.65±0.014	13.46±0.017	465
$t= TL_{(n)} - TL_{(n-1)}$	**All**	4.56	1.92	3.87	2.24	0.52	
	♂	6.95	4.38	2.69	1.4	2.44	
	♀	4.77	2.03	3.35	2.5	0.81	
% of increment	**All**	34.78	14.65	29.52	17.08	3.97	
	♂	38.91	24.52	15.06	7.84	13.67	
	♀	35.44	15.08	24.89	18.57	6.02	

When the back-calculation method was used, the average total lengths of age groups of *P. acarne* increased to (4.56, 6.95, 4.77) cm for all population, males and females, respectively in the first year of growth, reaching a maximum length of (13.11, 17.86, 13.46) cm for all population, males and females, respectively in the fifth year (Table 2), and the highest annual length growth rate was recorded in the first age group for all population, males and females (34.78%, 38.91%, 35.44%) respectively (Table 2).

Table (3): Length-Weight relationships parameters of *P. acarne* off Syrian waters.

	Total length (cm) Range	**Total weight (g) Range**	**a**	**b**	**R^2**
All	10 - 21.6	13.5 - 123.4	0.00561	3.292	0.97
♂	11.6 - 17.6	16.8 - 68.8	0.00607	3.263	0.95
♀	12.2 - 21.6	19.6 - 123.4	0.00564	3.290	0.97

Length-weight relationships were calculated separately for all population, males and females. The slopes (b values) of the length-weight relationships, which insignificantly different between sexes (ANCOVA, $P > 0.05$), indicate the positive allometric growth for all population, males and females (3.29, 3.26, 3.29) respectively (Table 3). The values of b for all population, males and females are insignificantly different from 3 (t-test, $P > 0.05$). When we have compared the present length growth with those from other areas, it is similar to that from Morocco (Mennes, 1985), Portugal (Santos *et al.*, 1995), Canarias Islands (Pajuelo & Lorenzo, 2000), Spain (Velasco *et al.*, 2011), Turkey (Soykan *et al.*, 2015; Ilhan, 2018) and Algeria (Bentata-Keddar *et al.*, 2020) (Table 5).

Table(4): Von Bertalanffy parameters for *P. acarne* off Syrian waters.

	L_∞ (cm)	**K**	**t_0 (year)**	**95% confidence**	**AIC**
All	19.78	0.23	- 0.044	10.49	8.81
♂	21.50	0.32	- 0.238	5.50	3.14
♀	22.97	0.18	- 0.239	17.64	6.09

The Von Bertalanffy growth model showed the following parameters (L_∞, K and t_0) for all population, males and females (Table 4). The asymptotic length L_∞ was 21.5 cm for males and 22.97 cm for females, and it is realistic since the largest individuals sampled were (17.6, 21.6) cm for males and females, respectively. The K coefficient was less than that indicated in the Mediterranean sea (Andaloro, 1982; Soykan *et al.*, 2015; Ilhan, 2018; Bentata-Keddar *et al.*, 2020) except that computed in Spain (Alboran sea) (Velasco *et al.*, 2011), and was greater than that in the Atlantic Ocean (Mennes, 1985; Pajuelo & Lorenzo, 2000; Coelho *et al.*, 2005; Velasco *et al.*, 2011), but the asymptotic length L_∞ in our study was the least compared to that in the other studies (Table 5). The differences are due to the eco-biological factors in each area. Accordingly, growth coefficient K in the males (0.32) was larger than this in the females (0.18), but the asymptotic length

L_∞ in the females was larger than this in the males, this means that males of *P. acarne* grew faster than females; which attributable to the fact that the Axillary seabream is a protandric hermaphroditic species, those results have also been observed for this species in several areas (Andaloro, 1982; Pajuelo & Lorenzo, 2000; Coelho *et al.*, 2005; Ilhan, 2018) (Table 5).

Table(5): Parameters of Von Bertalanffy growth and Length-weight relations of *P. acarne* from different localities.

Author	Location	L_∞ (cm)	K	t_0 (year)	φ_L`	a	b	n
Andaloro, 1982	Mediterranean (Italy)	♂ 26,23	0.42	-0.22				
		♀ 29.78	0.32	-0.26				
Mennes, 1985	Atlantic (Morocco)	All 31	0.21		2.3	0.02	3	
Santos *et al.*, 1995	Atlantic (Portugal)					0.085	3.15	
Pajuelo & Lorenzo, 2000	Atlantic (Canarias Islands)	All 32.98	0.22	-0.87		0.007	3.24	1966
		♂ 27.98	0.27	-0.67		0.007	3.24	
		♀ 33.90	0.21	-0.99		0.006	3.28	
Coelho *et al.*, 2005	Atlantic (Portugal)	All 32.05	0.18	-2.91				370
		♂ 28.82	0.29	-1.47				
		♀ 32.30	0.18	-2.56				
Velasco *et al.*, 2011	Atlantic (Spain)	All 31.65	0.21	-1.76	2.32	0.005	3.32	477
	Mediterranean (Spain)	All 32.14	0.17	-2.69	2.24	0.009	3.11	407
Soykan *et al.*, 2015	Mediterranean (Turkey)	All 22.66	0.32	-1.20	2.21	0.009	3.14	842
Ilhan, 2018	Mediterranean (Turkey)	All 25.61	0.25	-1.94	2.21	0.009	3.14	2036
		♂ 22.45	0.34	-1.55	2.24	0.015	2.94	
		♀ 27.75	0.20	-2.35	2.19	0.011	3.07	
Bentata-Keddar *et al.*, 2020	Mediterranean (Algeria)	All 29.97	0.41	-0.34	2.57	0.009	3.09	795
		♂ 28.43	0.42	-0.13	2.54	0.010	3.08	
		♀ 29.79	0.5	-0.04	2.64	0.013	2.98	
Present study	Mediterranean (Syria)	All 19.78	0.23	-0.04	1.95	0.006	3.29	1494
		♂ 21.5	0.32	-0.24	2.17	0.006	3.26	
		♀ 22.97	0.18	-0.24	1.97	0.006	3.29	

The growth performance index φ_L` was calculated for all population, males and females, and reached (1.95, 2.17, 1.97) respectively. And it is used to compare the growth rate of *P. acarne* in different localities which is less than that obtained by Mennes (1985), Velasco *et al.* (2011), Soykan *et al.* (2015), Ilhan (2018) and Bentata-Keddar *et al.* (2020) (Table 5). According to Musick's classification (1999), the resilience / productivity growth of *P. acarne* in this study was medium ($0.16 \leq k < 0.30$), and it is similar to that in Morocco (Mennes, 1985), Canarias Islands (Pajuelo and Lorenzo, 2000), Portugal (Coelho *et al.*, 2005), Spain (Velasco *et al.*, 2011), and Turkey (Ilhan, 2018), while it is considered high ($k > 0.30$) in Algeria (Bentata-Keddar *et al.*, 2020).

The maximum age T_{max} was 13 years and the maximum length L_{max} was 18.73 cm in the present study, while it was 12.05 years in the Gulf of Izmir (Ilhan, 2018). The resilience / productivity is therefore taken into account depending on the concept of maximum age T_{max}, which can be accessed for *P. acarne* during its lifetime in the both studies as low (T_{max}: 11-30 years) (Musick, 1999).

The mean length of the commercial capture was estimated as 9.38 cm (TL) for fishes ranging from 4.56 to 13.11 cm (TL). Consequently, the average age and length of the *P. acarne* at the first capture (T_c, L_c) were 1.78 years and 6.78 cm, respectively and the average age and length of individuals at recruitment (T_r, L_r) were 1.07 years and 4.48 cm, respectively. It is clear that the length at the first catch (L_c) in the Syrian waters is smaller than that computed in the Canaries Islands 16.1 cm (Pajuelo & Lorenzo, 2000).

Considering Beverton and Holt (1956), the age at first capture T_c is a true indicator of the mesh size used in practice or actually in fishing. Accordingly, the nets used for fishing of *P. acarne* from the Syrian coast were suitable (20 – 26 mm). This corresponds to what was previously indicated that the third age group and the individuals with the lengths (13.1 – 14 cm) were the predominant and higher than the age at first capture T_c and the length at first capture L_c previously defined. Thus, the *P. acarne* individuals in the Syrian waters were captured with relatively big sizes and ages.

Table (6): Mortality, exploitation and survival rates of *P. acarne* from different areas.

Author	Location	Z	F	M	A	S	E
Pajuelo & Lorenzo, 2000	Canaries Islands	0.96	0.66	0.30			0.69
Soykan *et al.,* 2015	Turkey	2.40	1.82	0.58			0.76
Present study	Syria	0.92	0.22	0.70	0.60	0.40	0.14

The instantaneous total mortality Z, corresponding to the slope of the descending limb of the catch curve, was 0.92 $year^{-1}$. The natural mortality M was 0.70 $year^{-1}$. Calculation of fishing mortality F gave 0.22 $year^{-1}$. With the values of M and F available, then exploitation ratio E was computed as 0.14 (Table 6). The rate F is significantly lower than those from the Atlantic (Pajuelo & Lorenzo, 2000) and the Mediterranean (Soykan *et al.,* 2015), but the M rate is higher than that from both areas (Table 6).

Fish are subject to a variety of environmental pressures (biotic and abiotic), in addition to the pressures from fishing and exhaustion of their numbers. Thus, there are two different phases in the life of these fish: the unexploited phase (from hatching to age at first capture T_c) and exploited phase (started from T_c) (Beverton and Holt, 1956).

From the present study it is noticed that the *P. acarne* is underwent to the exploited phase (started from T_c) due to exposure to fishing stress F and exploitation E, but at low levels. This shows that the *P. acarne* is in good and stable condition within their environment.

Fish during recruitment of population may be exposed to fishing mortality. This death often reaps the adult stages of the history of life, in contrast to the natural mortality that increases in the early stages (Sparre *et al.,* 1998), Small fish are also less likely to mortality fishing than large fish because they are able to pass through the nets or are far from fishing sites known to fishers (Gayanilo *et al.,* 1994).

Conclusions and Recommendations:

1. The age groups of *P. acarne* in the Syrian waters range between ($1^+ – 5^+$).
2. The largest individual of *P. acarne* caught from the Syrian coast is female at the length 21.6 cm (TL) and the age 5^+, while the smallest individual is juvenile at the length 10 cm (TL) and the age 1^+.
3. The length growth shows a positive Allometric growth for all population, males and females.
4. The resilience / productivity growth of *P. acarne* is medium ($0.16 \leq K < 0.30$), and depending on the concept of maximum age T_{max}, it has low value (T_{max} = 11 – 30 years).
5. The age and length at first capture T_c, L_c are 1.78 years and 6.78 cm, respectively and the age and length at recruitment T_r, L_r are 1.07 years and 4.48 cm, respectively.
6. *P. acarne* is underwent to the exploited phase (started from Tc) due to exposure to fishing stress F and exploitation E, but at low levels. This shows that the *P. acarne* is in good and stable condition within their environment.
7. The *P. acarne* in the Syrian waters are caught in relatively big sizes and ages.

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