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Research Article

Population structure of *Pagellus acarne* (Risso, 1927) in the North Aegean Sea

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Abstract

Sparidae family is one of the most important demersal group for Turkish fisheries. When considering the importance of Turkey fisheries, population parameters of *Pagellus acarne Risso*, 1827 give basic information for future fisheries studies. Studies of biology and population parameters of this species are very limited in the Aegean Sea; therefore we aimed to determine population parameters (length-weight relationship, age and growth parameters, mortality rates and, reproductive season) in order to obtain data for the future studies. We caught 2673 Pagellus acarne specimens between September 2006 to September 2008 from monthly samples at depths ranging from 20 to 500 m in the Saros Bay using a commercial bottom trawl net. Total length and weight range from 3.5 to 27.1 cm, 1.93 to 314.5 g, mean length and weight were 14.0±0.05 cm, 35.6±0.46 g respectively. The length-weight relationship was detected W=0.001*L3.054, which indicated positive allometric growth. The high GSI value was in September. The data on maturity stages indicated that length at 50% maturity (L50) for females 18.1 cm TL for males 15.3 cm TL. The age data derived from sagitta otoliths reading were used to estimate the growth parameters and ranged from 1-4 aged. The von Bertalanffy growth parameters of the total were L∞=30.63 cm, K=0.26 year-1, to= -0.95. The instantaneous total mortality was Z= 0.72 year-1, the natural mortality M = 0.54 year -1, the fishing mortality F=0.19 year-1 respectively. The exploitation ratio (E) of the stock was found as 0.26. Pagellus acarne is the most important marine fish species with high commercial value for both the Turkey coast and the Mediterranean basin. This study aims to define basic population parameters which should be needed for further fisheries studies and management strategies in Saros Bay, the North Aegean Sea.

Keywords: North Aegean Sea, *Pagellus acarne* (Risso, 1927), Length at Maturity, Reproduction, Mortality

Introduction

Axillary seabream, *Pagellus acarne* Risso, *1827*, a demersal fish belonging to the family Sparidae, is distributed along the European and African coasts of the Atlantic Ocean and in the Mediterranean including the Black Sea (Bauchot and Hureau 1986). This species can be found in diverse bottom types, particularly seagrass beds, down to the depth of 500 m, but is most frequent between 40 m and 100 m (Froese and Pauly 2020). The species is mainly carnivorous, and the important prey items are fish, Arthropoda, Mollusca, and Echinodermata (Morato et *al.*, 2001, Fehri-Bedoui et *al.*, 2009).

Pagellus acarne exhibits protandric hermaphroditism (Fischer et *al.*, 1987, Arculeo et *al.*, 2000, Dominguez 2000). The biology of this species has been reported in different regions of the Aegean Sea (Tosunoğlu et *al.*, 1997, Soykan et *al.*, 2015), and in the Greek waters (Stergiou et al., 1997). Several authors studied age, growth and reproductive biology of axillary seabream in the Mediterranean and Atlantic (Phân and Kompowski 1972, Andaloro 1982, Campillo 1992, Arculeo et al., 2000, Dominguez 2000, Pajuelo and Lorenzo 2000, Zoubi 2001, Coelho et al., 2005, Abecasis et al., 2008, Velasco et al., 2011, İlhan et al., 2018, Keddar et al., 2020, Di Maio et al., 2020).

Despite its commercial value and abundance along the Turkish coasts, there is a lack of information on population parameters of *Pagellus acarne* in the region which is to be known a particularly important fishery area due to its nutrient enrichment originated from several river inputs. Thus, the Saros bay was prohibited for commercial trawling in 1997 as a consequence of being subjected to overfishing until the 1990s (İşmen et al., 2010). In this study, we present age, von Bertalanffy growth parameters, reproduction season and, mortality rates of *Pagellus acarne* for the first time in the region in order to sustain preliminary information and basic population parameters which should be needed for further fisheries studies and management strategies in the in Saros Bay, the North Aegean Sea.

Materials and methods

Specimens of the Axillary seabream were collected at depths ranging from 20 m to 500 m in Saros Bay, North Aegean Sea monthly starting from September 2006 to September 2008. Samplings were carried out via using a commercial bottom trawl net. A total of 184 trawl operations took 30 minutes per each with 2.5 knots^{-1} hauling speed (Figure. 1).

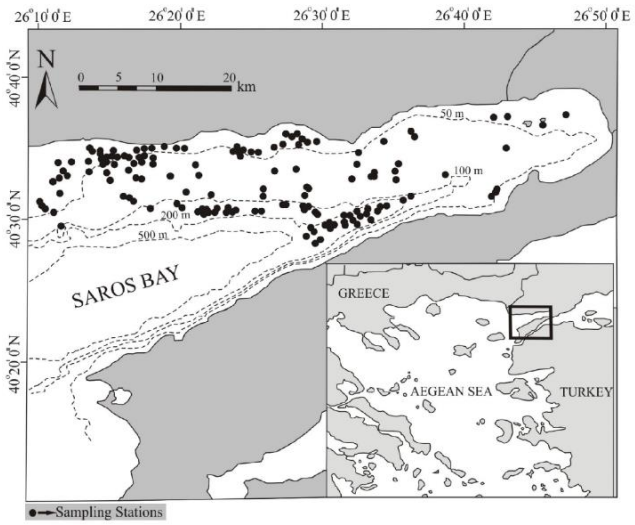

Figure 1. Sampling stations

Total length (TL) and total weight (TW) were measured to the nearest 0.1 cm and nearest 0.01 g respectively. The length-weight relationship was estimated with the formula: $W=aL^b$; a and b of the exponential curve were estimated by linear regression analysis over log-transformed data (log W = log a + b log L), where 'W' is the total body weight (g), L is the total length (cm), 'a' is the intercept and 'b' is the slope (Ricker 1975). Students' *t*-test was applied to evaluate whether the b value was significantly different from the isometric expected value of 3 (Pauly 1984).

During the study, the sex of 368 individuals was determined, and the reproductive season and length at 50% maturity (L_{50}) length were calculated. Gonad weight (WG) was determined to the nearest 0.01 g, and the sex and maturity stage was determined macroscopically. The stage of maturation was classified according to Holden and Raitt, (1974) as follows; immature (I), maturing virgin and recovering spent (II), ripening (III), ripe (IV), spent (V). The spawning season was estimated following the monthly changes of gonadosomatic index (GSI) which was calculated according to Anderson and Gutreuter 1983 as follows: $GSI = 100WG \times WE^{-1}$ where *W*G is the weight of the gonads, and *WE* is the weight of eviscerated fish.

The sex ratio (male: female) was calculated, and a chi-square test was used to detect differences in the sex ratio. L_{50} was defined as the size of which 50% of the individuals considered as mature (stage III, stage IV). Specimens were grouped into 1 cm size classes, and the proportion of mature (stage III, stage IV) and immature individuals was calculated (Fontana, 1968). The percentages of mature individuals by length class and sex were fitted to a logistic function using Newton algorithm from Microsoft Excel solver routine: $F(L) = (1 + e–(\beta 0 + \beta 1L))$–were F*(L)* is the proportion of mature fish at length *L*, $\beta 0$ is the intercept and $\beta 1$ is the regression coefficient (Piñeiro and Saínza 2003). Age was estimated by counting the annual growth rings on sagitta otoliths which were placed in glycerine solution and examined under a binocular microscope at 10 x with reflected lights against a dark background (Figure 2).

The von Bertalanffy growth parameters were estimated (von Bertalanffy 1938) according to the following equation: $Lt=L_\infty (1\text{-}e^{-K(1-t_0)})$ where L_t is the length at age t, L_∞ that the fish of a population would reach if they were to grow indefinitely, K is the growth coefficient and t_o is the hypothetical age the fish would have had at zero-length (Froese and Pauly 2020). Growth parameters were estimated according to the non-linear method using the FISAT II (FAO-ICLARM Stock Assessment Tools) package (Sparre et al., 1989).

The total instantaneous mortality rates (Z) were calculated from the length-converted catch curve (Pauly, 1983) using program FiSAT II (Gayanilo et al., 1994). Natural mortality (M) was calculated by Pauly's empirical equation (Pauly 1980):

Log (M) = -0.0066 – 0. 279 log (L_∞) + 0.6543 log (k) + 0.4634 log (T) : where M= natural mortality, L_∞ and K = von Bertalanffy growth parameters, T= the mean annual temperature (C^0) which is assumed to reflect the local temperature (During this study we used the mean surface temperature via CTD, T=14.1 C^0). The equation was calculated using the FISAT program (Gayanilo and Pauly, 1997). Fishing mortality rate (F) was estimated from the equation F= Z-M and exploitation of the stock rate (E) from E= F/Z (Sparre and Venema 1992).

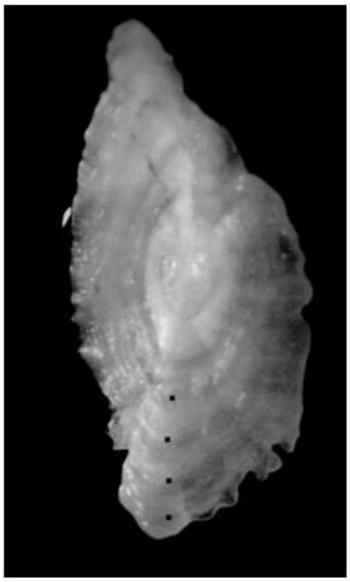

Figure 2. The right otholit of Pagellus acarne from North Aegean Sea

Results

A total of 2673 *Pagellus acarne* specimens were collected, ranging from 3.5 to 27.1 cm. Among 368 sexually defined specimens; 246 (67%), 117 (31%), and 5 (2%) of them were found as female-male and hermaphrodites respectively (Table 1).

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Table 1. Range and mean length and weight (±SE) of *Pagellus acarne* from North Aegean Sea

Sex	n	Total length		Total weight	
		Mean ± SE [cm]	Range [cm]	Mean ± SE [g]	Range [g]
Female	246	16.02 ± 0.5	11.8-27.1	56.4 ± 2.19	17-314.5
Male	117	16.7 ± 0.27	12-26.6	66.2 ± 3.89	19.5-303.6
Hermaphrodite	5	17.02±1.76	14.4-19.1	61.06 ± 16.3	38.16-77.14
Total	2673	14.0 ± 0.05	3.5-27.1	35.6 ± 0.46	1.9-314.5

**n= number of specimens, SE = standard error.*

Table 2. Length-weight relationship parameters for female and male *Pagellus acarne* from Saros Bay

Sex	n	a	b	R^2	*p*
Female	246	0.005	3.277±0.04	0.95	*p< 0.05*
Male	115	0.004	3.364 ±0.07	0.94	*p< 0.05*
Total	2673	0.001	3.054 ±0.01	0.94	*p< 0.05*

**n= number of spicemens, a= intercept, b= slope of the regression, R^2= coefficient of determination, p = significance level (t-test).*

The length distribution of axillary seabream indicated that the most frequent size class in females and males was the 16 cm length class (Figure 3). The size-frequency distribution for males and females were not significantly different (Kolmogorov-Smirnov two-sample test p >0.05). The overall sex ratio was 1:2.1 males to females and was significantly different from the expected 1:1 ratio (p<0.05, X^2). According to the estimated b values, positive allometric growth was evident in all cases (t-test, p<0.05) (Table 2). The slopes of the regressions estimated for males and females did not differ (p>0.05) (Figure 4).

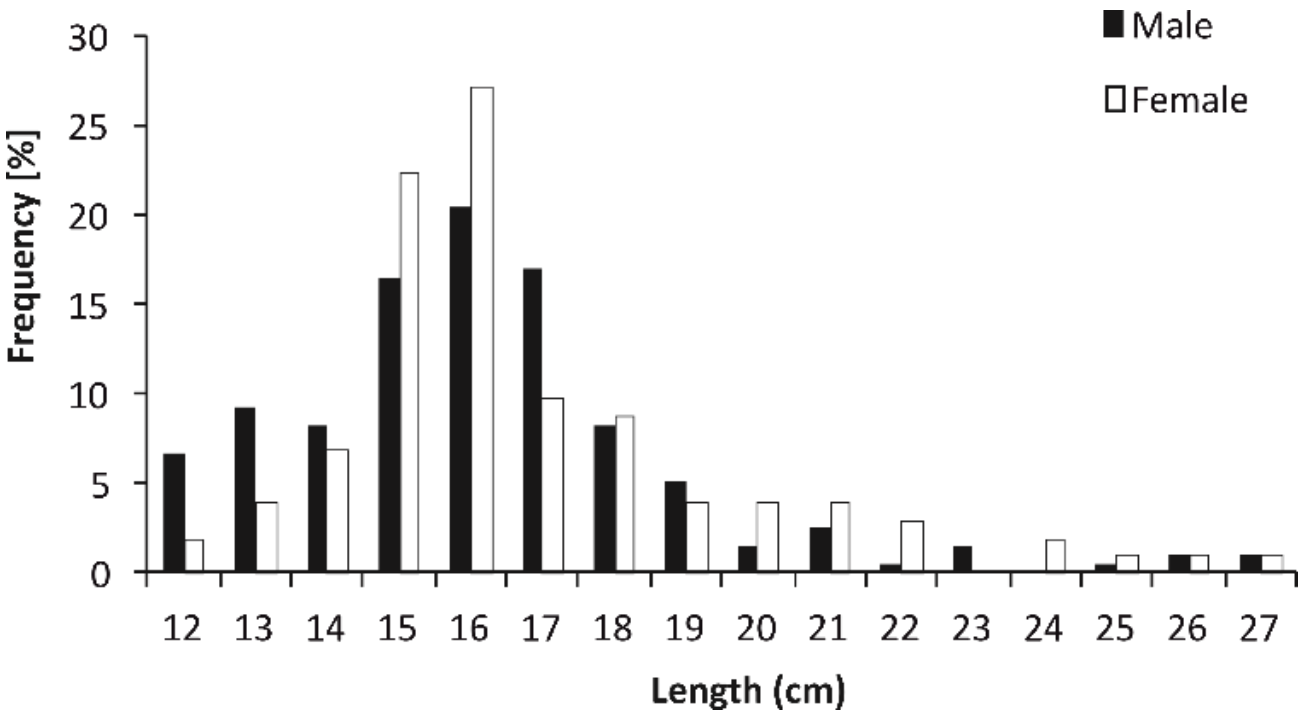

Figure 3. Length frequency distribution of *Pagellus acarne* from Saros Bay by sex.

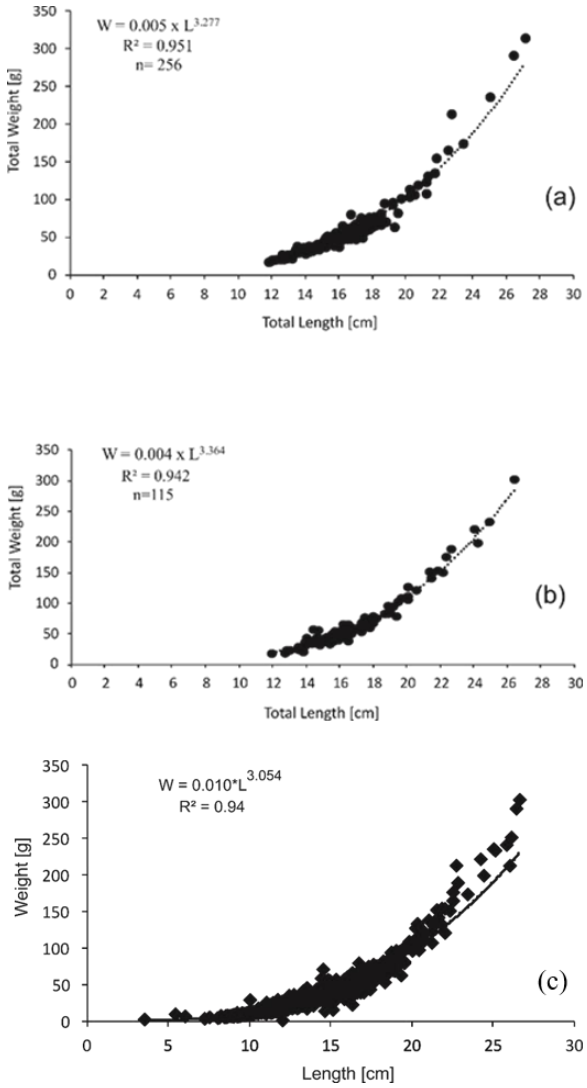

Figure 4. Length-weight relationship of *Pagellus acarne* from Saros Bay. (a: female, b: male, c: total).

Females with mature gonads (stage III and stage IV) were recorded between August and November. Spent females (stage V) were recorded in September and November (Figure 5). GSI values declined sharply after September (Figure 6) and then started to increase slowly between November and April, followed by a rapid increase until August 2007. The same almost pattern was followed in the next period. Monthly changes in the GSI suggest that gonad growth was remarkably high between August and September. The monthly variation of GSI and also maturity stages showed that the spawning period occurs between August and October. Size at maturity (L_{50}) was estimated to be 18.1 cm for females and 15.3 cm for males (Figure 7).

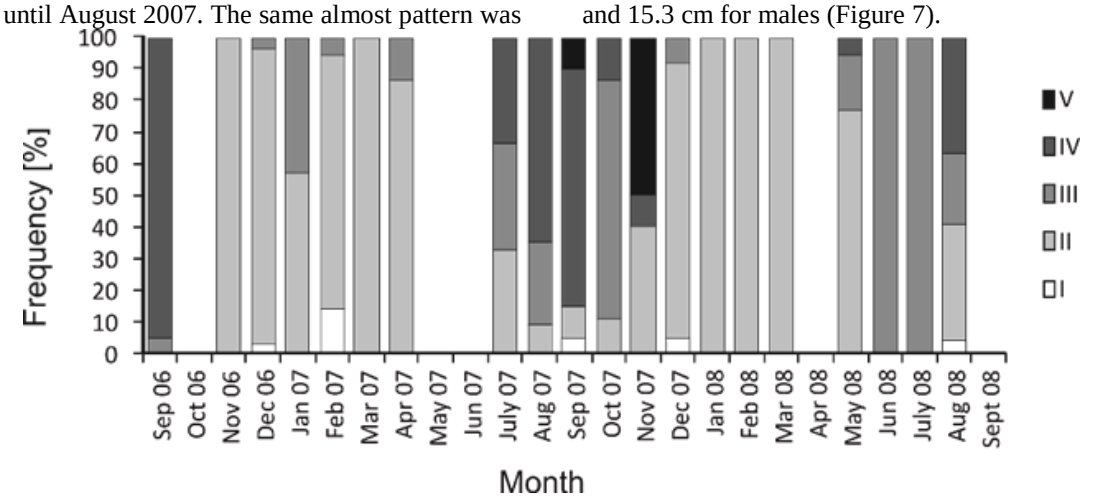

Figure 5. Maturity stage frequency for females of Pagellus acarne from Saros Bay by month (I= immature, II= maturing virgin and recovering spent, III=ripening, IV= ripe, V=spent)

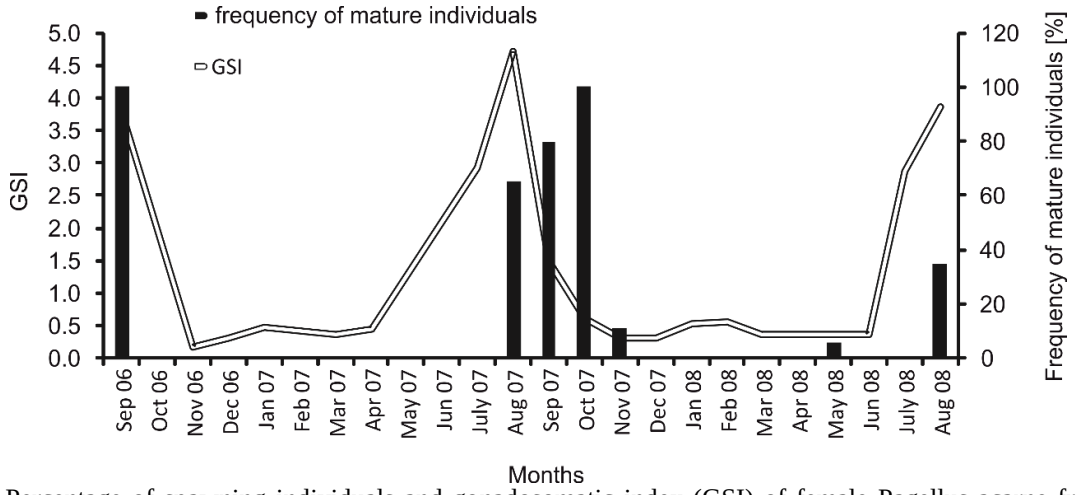

Figure 6. Percentage of spawning individuals and gonadosomatic index (GSI) of female Pagellus acarne from North Aegean Sea by month.

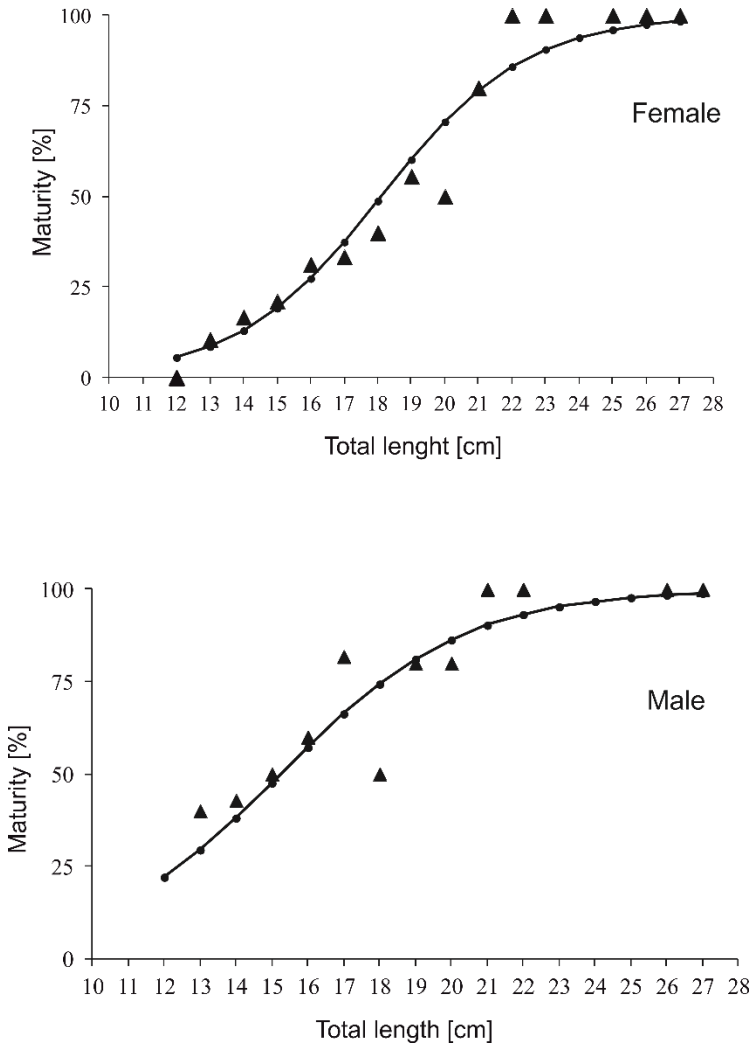

Figure 7. Percentage of sexually mature females and males Pagellus acarne from North Aegean Sea by size class.

Age was estimated for 194 specimens. Age ranged from 1 to 4 years. The dominant age group was 1 year (40%), followed by age 2 (42%), age 3 (15%), and age 4 (3%). Growth parameters which calculated with the von Bertalanffy equation were estimated as L_{∞}=30.63 cm, K=0.26 year^{-1}, t_o= -0.95 year (Figure 9). The total length-otolith length relationship was calculated as follows: OL=0.305×TL +1.421 (R^2 =0.81).

The total mortality, Z, were estimated at 0.72 year^{-1} while natural and fishing mortality was calculated as M =0.54 year^{-1} and F = 0.19 year^{-1}, exploitation rate (E) of stock was estimated to be 0.26.

Table 3. Growth parameters of Pagellus acarne from various geographic areas.

Author	Location	Age	Sex	L_∞	K	t_o	Ø
Phân and Kompowski,1972	Mauritania	-	-	36.0	0.23	-0.97	2.47
Andaloro, 1982	Mediterranean	1-8	-	28	0.37	-	2.46
Mennes, 1985[1]	Morocco	-	-	31	0.21	-	2.3
Papaconstantinou et al.,, 1988[1]	Ionian Sea	-	-	32.1	0.17	-1.67	2.23
Campillo 1992	Italy	-	-	28.0	0.37	-	2.46
Djbali et al.,, 1990	Algeria	-	-	24.4	0.3	-	2.25
Tosunoğlu et al.,, 1997[1]	M. Aegean Sea	1-3	-	21	0.17	-3.22	1.88
Pajuelo and Lorenzo, 2000	Canary Island	1-10	M	30	0.27	-0.67	2.39
Pajuelo and Lorenzo, 2000	Canary Island	1-10	F	33.9	0.21	-0.99	2.38
Dominguez, 2000	Alboran Sea	-	-	29.62	0.27	-1.36	2.39
Zoubi, 2001	Morocco	-	-	24	0.43	-0.21	2.27
Coelho et al.,, 2005	Portugal (South)	1-18	-	32.05	0.18	-2.91	2.38
Coelho et al.,, 2005	Portugal (South)	1-13	M	28.82	0.29	-1.47	2.27
Coelho et al.,, 2005	Portugal (South)	1-18	F	32.3	0.18	-2.56	2.29
Abecasis et al.,, 2008	Portugal	1-16	-	31.84	0.19	-2.86	2.20
Velasco et al.,, 2011	Cadiz Bay	1-7	-	31.65	0.21	-1.76	2.32
Velasco et al.,, 2012	Alboran Sea	1-7	-	32	0.17	-2.69	2.24
Soykan et al.,, 2015	M. Aegean Sea	1-6	-	22.66	0.31	-1.20	2.21
İlhan, 2018	Central Aegean Sea	1-4	-	25.61	0.24	-1.94	-
Keddar et al.,, 2020	Mediterranean	-	-	29.97	0.41	-0.34	2.57
Present study	N. Aegean Sea	1-4	-	30.63	0.26	0.95	2.39

*[1]= *based on fork length*

Discussion

The maximum total length of *Pagellus acarne* in Saros Bay was determined as 27.1 cm. Other studies in the Aegean Sea reported that maximum total length values were lower than the ones within the present study (Karachle and Stergiou 2008, Soykan et al., 2015) except for 62.2 cm TL reported as the maximum in Greek waters (Moutopoulos and Stergiou 2000).

Both female and male *Pagelus acarne* exhibit positive allometric growth as previously reported for Mediterranean and Atlantic coast (Pajuelo and Lorenzo, 2000; Morey et al.,, 2003; Coelho et al., 2005; Ceyhan et al.,2009; Velasco et al., 2010; Soykan et al., 2015; İlhan 2018; Di Maio et al.,2020). On the contrary in the Aegean Sea, Moutopoulos and Stergiou (2002) found that negative allometry for *Pagellus acarne* in the Aegean Sea.

Axillary seabream displays protandric hermaphroditism as it had been reported (Alekseev 1967, Andolora 1982, Lamrini 1986, Buxton and Garratt 1990, Pajuelo and Lorenzo 2000, Di Maio et al 2020). The sex ratio of males to females calculated in the present study as 1:2.1 was similar to those reported in the studies published by Arculeo et al., (2000), Pajuelo and Lorenzo (2000) and Velasco et al., (2011) and Soykan et al., (2015). We observed that the female individuals within the same size group had outnumbered which supports the previous suggestion. Besides, according to Pajuelo and Lorenzo (2000), Valesco et al., (2011), Di Maio et al., (2020) protandric hermaphroditism may explain the differences between females and males in the length-weight relationship; however, we did not find statistically significant differences in the length-weight relationship between males and females ($p > 0.05$). Also, Di Maio et al., (2020) calculated the length of sexual inversion as 22 cm TL of *P. acarne* in the Strait of Sicily, on the contrary, these results, we observed the 26.6 cm male specimens in the North Aegean Sea. It is important to obtain a piece of certain knowledge about the aspects of this species being protandric hermaphrodite; however, histological gonadal development data analysis was not performed in our study, the population of *Pagellus acarne* in the Northern Aegean Sea was not decisively classified as a protandric hermaphrodite species due to the inconsistency of our findings above. Reproductive season was observed in summer and autumn months. Spawning period appears to extend from August to October with a peak in September while resting period occurred mainly during the winter months. Previous studies support the present results of the reproductive season in this study (Andaloro 1982, Lamrini 1986, Santos et al., 1995, Arcuelo et al., 2000, Coelho et al., 2005, Velasco et al., 2011, Soykan et al., 2015; Di Maio et al., 2020). Phân and Kompowsky (1972) and Pajuelo and Lorenzo (2000) reported that the reproductive season was in winter and spring months in the Northwest African coasts and the Canary Islands, respectively. This difference could be derived by environmental factors,

particularly temperature, which is crucially important for reproduction activities of fishes (Wootton 1990).

The value of L_{50} was evaluated as to be lower for males than for females. Based on the age results of the present study, males and females become sexually mature at the ages of 1 and 2, respectively. Pajuelo and Lorenzo (2000) reported L_{50} values as 15.8 cm for males (at the age of 2), and 19.4 cm for females (age of 3) in the Canary Islands. Coelho et al., (2005) found this values as 18.1 to 17.60 for males and females respectively in the south coast of Portugal, Lamrini (1986) indicated that 20.9 cm in the northwest Africa coast and lastly Soykan et al., (2015) determined the L_{50} values as 14.5 cm for females, 13.9 cm for males in the Central Aegean Sea.

Information about age is fundamental for estimating growth and mortality rates (Campana 2001). The estimation of the age of fishes is generally based on the counting of rings or marks on otoliths or scales (Campana and Neilson 1985, Morales-Nin 1992). The Axillary seabream has observable and interpretative otolith for age estimation (Erzini et al., 2001, Coelho et al., 2005, Abecasis et al., 2008 and Velasco et al., 2011). The oldest age recorded for *Pagellus acarne* was 18 years old in Portugal reported by Coelho et al., (2005). In the Aegean Sea, age composition of this species was reported by Tosunoğlu et al., (1997) as to be between 1-3 years and by Soykan et al., (2015) as to range between 1-6 years. The total length of fishes is linearly related to otolith length. Estimating the size of total length can be performed with fair reliability based on otolith length also, the otoliths which found in gut contexts of predators can be used to specify the fish species and to determine their size (Jobling and Breiby 1986, Wigley et al., 2003, Dietrich et al., 2006). Therefore, we determined otolith size of *Pagellus acarne* and relation with the total length in order to contribute a data for the further studies regarding this species. There is no data concerning the total length-otolith length relation in the Aegean Sea and the Mediterranean. However, Velasco et al., (2001) calculated the relationship between the total length and otolith radius in Southern Spain.

The results of previous studies about von Bertalanffy growth parameters performed in the Middle Aegean Sea for *Pagellus acarne* (Soykan et al., (2015): L_{∞} = 22.6 and K=0.315 year^{-1} t_o=-1.20 and Tosunoğlu et al.,, (1997): L_{∞}= 21 cm, K= 0.17 year^{-1} and t_o= -3.22) differ from our growth findings, however, according to the Munro's phi-phrime test indicated that there were no significant differences between von Bertalanffy growth parameters of other studies (t_s<t_t). Such differences can be originated because of depths of the sampling area which might affect the size distribution of individuals in catch also Table 4 indicates that the length range of the study abovementioned (Soykan et al., 2015) is narrow compared to our range.

A few studies about mortality rates of *Pagellus acarne* were performed in the middle Aegean Sea, Gurbet et al., (2012) reported that Z=1.94 year^{-1}, M=0.68 year^{-1}, F=1.26 year^{-1} and E=0.65 while, Soykan et al., (2015) stated that Z=2.395 year^{-1}, M=0.579 year^{-1}, F=1.816 year^{-1} and E=0.758. It is clear that these values are extremely higher than our mortality results which are total (Z), natural, fisheries and exploitation rate, respectively, in addition to this Pajuelo and Lorenzo (2000) presented mortality rates in the Canary Islands, Z=0.96 year^{-1}, M=0.30 year^{-1}, F= 0.66 year^{-1} and E=0.69.

In conclusion, one of the most notable results of this study is the L_{50} value and the size-frequency distribution of the female specimens. Although we obtained similar results with the studies conducted in different regions of Mediterranean in terms of L_{50}, we could not certainly confirm the protandric hermaphroditism of the North Aegean stocks for this species. This argument is based on our estimation of L_{50} value of female *P. acarne* that was smaller than the considered length of sex inversion according to the studies from Mediterranean. Besides, the differences in the von Bertalanffy growth parameters can be explained by the difference in length range which might be derived from different depth ranges of trawl operations. Saros Bay is a banned area for commercial fisheries activities; thus mortality rates, especially fisheries mortality and exploitation rate results, were consistent with the expected.

Acknowledgements

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