THALASSAS

Thalassas, 2005, 21 (1): 79-84
An International Journal of Marine Sciences

AGE, GROWTH AND REPRODUCTION OF THE AXILLARY SEABREAM, *PAGELLUS ACARNE* (RISSO, 1827), FROM THE SOUTH COAST OF PORTUGAL

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Keywords: *Pagellus acarne*, Sparidae, age, growth, reproduction, maturity.

ABSTRACT

Axillary seabream, *Pagellus acarne*, caught by longlines in the Algarve (Southern Portugal), were sampled between August 1995 and August 1996. Age was studied by counting growth increments on otoliths and the estimated von Bertalanffy parameters were L_{inf} = 28.82 cm, K = 0.29 year^{-1} and t_0 = -1.47 year for males and L_{inf} = 32.30 cm, K = 0.18 year^{-1} and t_0 = -2.56 year for females. Evidence of the annual periodicity of the deposition of increments was found by marginal increment analyses. Macroscopic analysis of the gonads and the gonad somatic index showed that reproduction occurred over an extensive period of time, from May to November. Lengths at first maturity were 18.10 and 17.60 cm for males and females, respectively. This species was characterized as being a protandric hermaphrodite.

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INTRODUCTION

Sea breams (Sparidae) are a dominant component of the Algarve continental shelf demersal fish community (Gomes *et al*., 2001). More than 20 species are found in Algarve (south Portuguese) waters and many are among the more valuable of the commercial and recreational fish species. One of these important species is the axillary seabream, *Pagellus acarne* (Risso 1827). This demersal fish species inhabits various types of sea bottom, especially seagrass beds and sand down to 500 m depth, but is more common between 40 and 100 m. It has a wide geographical distribution along the European and African coasts, from Denmark to Senegal, and around the Madeira, Azores, Canary and Cape Verde Islands. It also occurs in the Mediterranean and in the Black Sea (Bauchot & Hureau, 1986). The biology of this species has been studied in the Mediterranean (Andaloro, 1982; Stergiou *et al*., 1997), the Atlantic coast of Morocco and Western Sahara, (Mennes, 1985; Lamrini, 1986) and the Canary Islands (Pajuelo & Lorenzo, 2000). In Portugal, research has focused mainly on longline (Ezini *et al*., 1998) and gillnet (Santos *et al*., 1995) selectivity.

Total landings of sea breams in the Algarve have declined in recent years from a combined total of

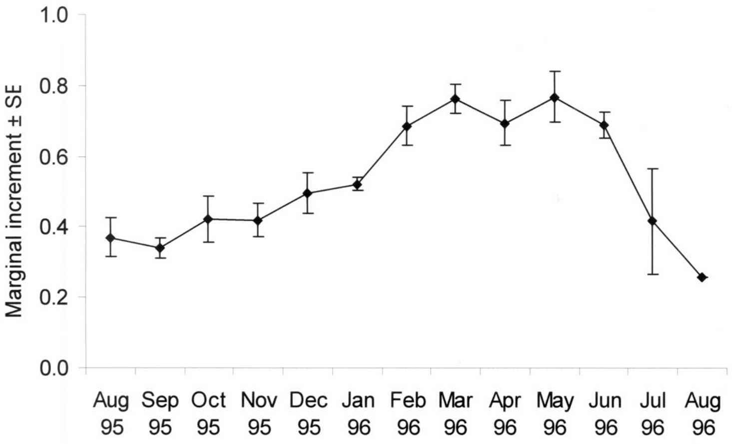

Figure 1.
Mean marginal increment in otoliths of P. acarne by month. The error bars represent ± standard error (SE).

approximately 4000 t per year in 1987 to less than 2000 t per year in 2000. This decrease in landings has been very accentuated in the case of *P. acarne*. Regarding the entire Portuguese coast, landings of *P. acarne* have decreased from 1949 t in 1988 to 1254 t in 2000, representing a reduction of 35.6 %. In the Algarve, the reduction in recent years was even greater (40.1%), with landings decreasing from 1071 t in 1987 to 641 t in 2000 (DGPA, 2000).

These trends underline the urgency and necessity for research on this species. In order to provide useful information for decision making, and to allow better management, it is important to carry out the basic research which provides the parameters necessary for stock assessment. In this study, we focused on aspects of the population biology of *P. acarne* from the Algarve, studying age, growth and maturity in fish exploited mainly by longlines.

MATERIAL AND METHODS

Biological sampling took place on the south coast of Portugal (Algarve), between August 1995 and August 1996. A total of 370 fish were captured, mostly from commercial longliners operating along the Portuguese South coast. The entire sample was brought to the laboratory where total length (TL, cm), total weight (Wt, g) and eviscerated weight (We, g) were measured. The date and location of capture were recorded, along with other data such as hook size and bait used. Saggitta otoliths were removed, cleaned in distilled water and air dried. Gonads were removed, weighed and classified. Morphometric relations were established between TL and Wt.

To estimate age, whole otoliths were immersed in glycerol and observed with a compound microscope with amplifications between 10 and 40x, with a black

Table 1.
Growth parameters of P. acarne estimated by non-linear regression from otolith readings, for all fish, males and females. All estimates are followed in brackets by the lower to upper limits of the 95 % confidence interval.

Sample	n	Von Bertalanffy Growth Parameters		
		t_0 (year)	K ($year^{-1}$)	L_{inf} (cm)
All fish	365	-2.91 (-3.44 to -2.38)	0.18 (0.15 to 0.20)	32.05 (30.95 to 33.14)
Males	80	-1.47 (-2.21 to -0.72)	0.29 (0.21 to 0.38)	28.82 (27.18 to 30.46)
Females	156	-2.56 (-3.12 to -1.99)	0.18 (0.15 to 0.21)	32.30 (31.03 to 33.58)

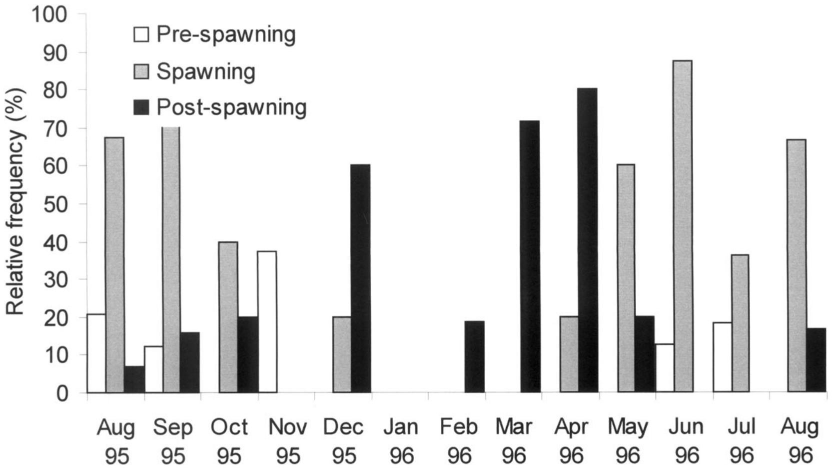

Figure 2.
Monthly variation of relative frequency for maturity stages of pre, during and post spawning for females of P. acarne.

background and under reflected white light. All otoliths were read independently by between three and six experienced researchers, and age was only assigned for otoliths where at least three of the researchers were in agreement. Researchers did not have access to information on size, sex or date of capture while they were counting growth increments. To quantify the efficiency of age estimations between readers, the percent of concordant readings was calculated, comparing the percent of readings discordant in 0, +/- 1, +/- 2, +/- n years.

Marginal increment analysis was used to validate the periodicity of the formation of the growth increments. According to Beamish & McFarlane (1983), this method is a simple and direct way to validate age estimations, given that the variation of the distance of the opaque band to the border of the otolith throughout the year gives an indication of the time of the year when the bands are deposited. For this analysis, 10 otoliths were selected for each month. These otoliths were observed with a compound microscope and measurements taken with an ocular micrometer. The total length of the otolith (Rt) was measured along the dorso-ventral axis, as was the radius (R - the distance from the focus to the margin) and the distance from the focus to the last ring (Rn) and the penultimate ring (Rn-1). The monthly mean marginal increment (MI) was then calculated by:

$$MI = \frac{(R - R_n)}{(R_n - R_{n-1})}$$

The von Bertalanffy growth function was fitted to the individual length-at-age data of all aged specimens by the non-linear least square method (NLIN procedure in SAS (1988)). Growth parameters were compared between sexes using the Hotelling's T^2 test (Bernard, 1981).

The reproductive cycle and size at first maturity of the axillary seabream was studied by macroscopic analysis of the gonads. Laboratory studies were carried out and the sex and the maturity stage of specimens determined either visually directly by eye or by compound microscope. The maturation classification stages were adopted from a number of others used for synchronous and total spawners (Lagler, 1978).

The gonad somatic index (GSI) (Htun-Han, 1978) was used to identify the spawning period:

$$GSI = 100 \times (\text{gonad weight (g)} / We\ (g))$$

The proportion of mature individuals by size class was used to fit maturity ogives and to estimate the size at first maturity (TL where 50% of the individuals are mature). The logistic curve was fitted by non-linear regression using the NLIN procedure in the SAS (1988) system:

$$P_i = \frac{1}{1 + e^{-b(L_i - L_{50})}}$$

where P_i is the proportion of mature individuals in size class L_i, b is the slope and L_{50} is the size where 50% of the individuals are mature ($P_i = 0.5$).

Maturity ogives were fitted to males and females separately and compared with the Hotelling's T^2 test (Bernard, 1981).

RESULTS

Of the 370 specimens collected for population dynamics studies, 82 (22.2%) were males, 159 (43.0%) were females, 15 (4.1%) were immature and 106 (28.6%) were hermaphrodites. The sex of 8 individuals (2.2%) could not be determined. The mean total length of males (mean = 23.9 cm, sd = 2.9, range: 15.9 to 30 cm) was significantly different from the mean total length of females (mean = 25.8 cm, sd = 3.0, range: 16.7 to 36.5 cm) (t student test: $P < 0.001$).

A significant relationship between TL and Wt was found (ANOVA: $P < 0.01$):

$$Wt = 0.012 \times TL^{3.048}$$

($r^2 = 0.98$, n = 370, Range: 12.4 to 36.5cm TL)

The otoliths from the 370 fish were used for age determination. In general, the otoliths were easy to read and only 5 specimens could not be aged. The percentage of concordance between the different readers was 80.6%. Percentage of discordance was 17.5%, 1.4%, 0.2%, 0.2% and 0.1% for +/- 1, +/- 2, +/- 3, +/- 4 and +/- 5 years, respectively.

Overall, the best represented age classes were from 1 to 8 (90.8% of the sample). Most of the male specimens were aged between 2 to 5 years (65.9%), and only one male was estimated to be older than 8 years. This large specimen with 30cm TL was estimated to be 13 years. Most of the females were between 3 and 7 years (71.1%). The youngest hermaphodite was 2 years old and most of these specimens were between 3 and 6 years (72.6%). All immature specimens were determined to be either age 0 or 1.

Through the marginal increment analysis, it was possible to validate age estimations. It was observed that one pair of bands (one opaque and one translucent) was formed each year. The opaque band started to form in July, corresponding to a sharp decrease in the marginal increment. During the rest of the year there was a progressive increase in the marginal increment (Figure 1).

The estimated von Bertalanffy parameters, along with the respective confidence intervals are presented in Table 1. Significant differences between males and females were found in these parameters (Hotelling T^2 test: $P < 0.05$). The observed and predicted lengths-at-age for all fish, males and females are summarized in Table 2.

Table 2.

Summary of length-at-age data for P. acarne using otoliths. All values refer to the total length in cm. SD refers to the standard deviation.

Age	All Data				Males				Females			
(year)	n	Mean ± SD	Range	Predicted	n	Mean ± SD	Range	Predicted	n	Mean ± SD	Range	Predicted
0	4	13.33 ± 0.77	12.4-14.1	13.07								
1	43	18.75 ± 1.12	15.9-22.7	16.19	15	19.79 ± 2.38	15.9-22.7	14.74	8	19.89 ± 1.43	16.7-21.2	15.28
2	24	21.40 ± 0.87	20.4-23.3	18.81	7	21.71 ± 0.67	20.7-22.8	18.28	7	21.43 ± 1.01	20.4-23.3	18.09
3	45	22.80 ± 0.91	20.9-24.8	20.99	12	22.83 ± 0.73	21.8-24.2	20.94	15	22.54 ± 0.90	20.9-24.1	20.43
4	60	23.96 ± 0.69	21.8-25.5	22.81	17	24.01 ± 0.83	22.4-25.5	22.92	16	23.86 ± 0.53	23.0-24.5	22.38
5	52	25.57 ± 0.97	23.2-28.0	24.33	11	25.18 ± 1.03	23.6-26.8	24.41	24	25.51 ± 0.81	23.2-27.1	24.02
6	51	26.31 ± 0.76	25.0-28.8	25.60	4	26.60 ± 1.46	25.1-28.0	25.52	32	26.07 ± 0.71	25.0-27.7	25.38
7	44	27.19 ± 0.93	25.4-28.8	26.67	8	27.40 ± 0.69	26.6-28.8	26.35	25	27.15 ± 0.95	25.4-28.8	26.52
8	18	27.97 ± 0.75	27.0-29.7	27.55	5	27.44 ± 0.30	27.0-27.8	26.97	9	28.32 ± 0.86	27.1-29.7	27.47
9	7	29.39 ± 0.76	28.5-30.5	28.29				27.44	6	29.45 ± 0.73	28.5-30.5	28.27
10	5	29.72 ± 0.67	28.8-31.3	28.91				27.78	4	29.88 ± 1.15	28.8-31.3	28.93
11	3	30.03 ± 1.11	29.2-31.3	29.43				28.05	3	30.03 ± 1.12	29.2-31.3	29.49
12	2	30.55 ± 1.77	29.3-31.8	29.86				28.24	1	29.30		29.95
13	3	30.90 ± 1.01	30.0-32.0	30.22	1	30.00		28.39	2	31.35 ± 0.92	30.7-32.0	30.34
14	2	31.80 ± 2.26	30.2-33.4	30.52					2	31.80 ± 2.26	30.2-33.4	30.66
15				30.77								30.93
16				30.98								31.16
17				31.16								31.34
18	2	35.75 ± 1.06	35.0-36.5	31.31					2	35.75 ± 1.06	35.0-36.5	31.50

Table 3.
Bio-geographic comparison of biological parameters for P. acarne. K, Linf and t0 refer to the von Bertalanffy growth parameters and M50 refers to length at first maturity. LFA refers to length frequency analyses. Values with an asterisk (*) refer to measurement of fork length while all the others refer to total length.

Author	Location	Sampling method	Sampling date	Size range (cm)	Method	Sex	K ($year^{-1}$)	L_{inf} (cm)	t_0 (year)	M_{50} (cm)	Reproductive season
Andaloro (1982)	Tyrrhenian and Ionian Seas	Trammel net and beach seines		8 to 28	Otoliths	Males	0.42	26.23	-0.22	16.5	July to September
						Females	0.32	29.78	-0.26		
Mennes (1985)	Western Sahara	Trawl	1980 to 1982		LFA	All fish	0.21	31.00*			
Lamrini (1986)	Western Sahara	Trawl	March to November 1981							20.9	Peak in Summer
Stergiou *et al.* (1997)	Greece		1986 to 1988		Otoliths	All fish	0.17	32.10*	-1.69	13.5*	June to December
Pajuelo and Lorenzo (2000)	Canary Islands	Longline and traps	January 1991 to December 1994	11 to 31	Otoliths	All fish	0.22	32.98	-0.87		October to March
						Males	0.27	27.98	-0.67	15.8	
						Females	0.21	33.90	-0.99	19.4	
Present study	South Portugal	Longline	August 1995 to August 1996	12.4 to 36.5	Otoliths	All fish	0.18	32.05	-2.91		May to November
						Males	0.29	28.82	-1.47	18.1	
						Females	0.18	32.30	-2.56	17.6	

Hermaphrodite fish accounted for 30.5% of the mature specimens. Hermaphrodite males were dominant in the smaller size classes while hermaphrodite females occurred only in size classes of 18 cm and greater. All fish in size classes greater than 31 cm were females.

The axillary seabream has an extensive spawning season, from spring to autumn. Most spawning females were found from May to October. Post-spawning stages occurred mostly from December to April (Figure 2). The analysis of the GSI indicated a similar spawning period as that found by analysis of maturity stages. In general, the highest values started in May and were observed until September in males and November in females (Figure 3). Again, the resting period was observed from December to April.

Lengths at first maturity were 18.1 and 17.6 cm TL for males and females respectively. Although these values are relatively similar, the maturity ogives presented statistically significant differences (Hotelling T^2 test: $P < 0.05$) (Figure 4).

DISCUSSION

The observation and interpretation of the otoliths was very consistent, based on the independent and concordant readings of at least 3 different observers, revealing the adequacy of these structures for estimating age of the axillary seabream. Previous studies that have used otoliths to age *P. acarne* include Andaloro (1982) and Pajuelo & Lorenzo (2000).

The marginal increment analyses in the otoliths showed that a pair of bands (one opaque and one translucent) was deposited with an annual periodicity, with the opaque band starting to be deposited in the summer, in July. The relatively large standard error in this month might be due to the fact that part of the individuals already started to deposit the opaque band and have a small marginal increment (close to 0) while others are still depositing the translucent band and have large marginal increments (close to 1). This analysis validated the use of otoliths for assessing age in this species. Pajuelo & Lorenzo (2000) had already demonstrated this annual deposition pattern for this species in the Canary Islands. According to these authors, the opaque band was deposited mostly during the summer, when water temperature is higher and food is more abundant.

The von Bertalanffy growth curve fitted to otolith based age-length data adequately explains the growth pattern for the observed size range of the axillary seabream. The fitted growth model probably does not properly describe juvenile growth in this species because of the lack of individuals smaller than 12.4 cm in the sample. Beach seines used inside the Ria Formosa coastal lagoon, an important nursery area in

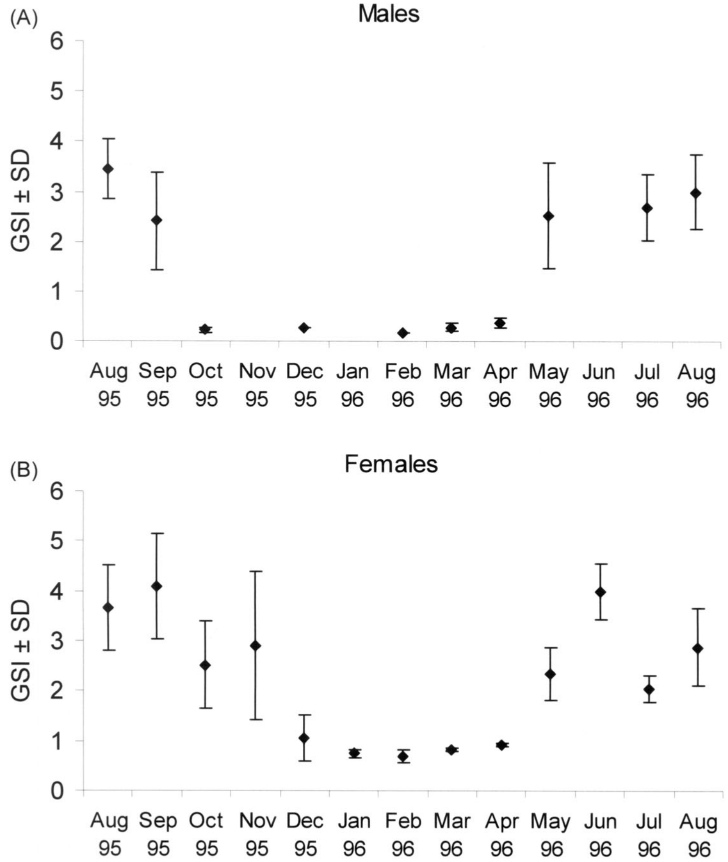

Figure 3.
Gonad somatic index (GSI) by month for males (A) and females (B) of P. acarne. The error bars represent ± standard deviation.

the Algarve, proved effective in the capture of juveniles of other sparid species, but not the axillary seabream. This could be due to the fact that juveniles of this species are not found in these coastal lagoons during their early life stages but, instead, live in the adjacent coastal areas. Since they are not yet recruited to the fishery they are not captured with the traditional commercial fishing gears that operate in these areas. The estimated growth parameters are similar to the ones reported by other authors for the Mediterranean, the Western Sahara and the Canary Islands (Table 3). The only author whose values are divergent from this tendency is Andaloro (1982) who obtained higher values of K and lower values of Linf for species from the eastern Mediterranean.

The fact that males appear mostly in the lower length classes and females in the higher classes, with significant differences detected in the mean lengths-at-age of males and females, indicates that this is probably a protandric hermaphroditic species. This type of hermaphroditism may also be evidenced by the fact that females have a lower growth rate and a larger asymptotic maximum length. Therefore, in the earliest years of life, when the growth rate is higher, the individuals are mainly males while, on the other hand, in the older age classes when the growth rate is lower most of the individuals are females. This type of hermaphroditism had already been described for this species (Lamrini, 1986; Arculeo *et al*., 2000; Pajuelo & Lorenzo, 2000). Even though we cannot specify the

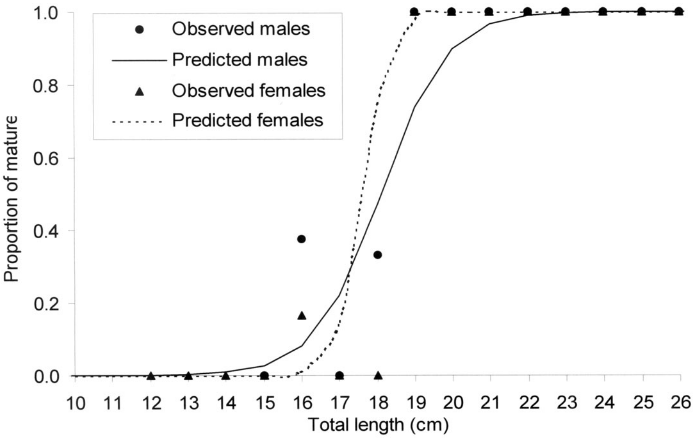

Figure 4.
Maturity ogives for males and females of P. acarne, with the respective 1cm total length class observed values.

length and age of sexual inversion, this probably occurs between 20 and 24 cm TL (between 3 to 6 years of age), since it is during this period that male and female proportions are identical. In the lower length classes, the sex ratio is in favor of the males and above 24 cm of total length this trend is reversed and the sex ratio favors females. These values are similar to the ones found by Andaloro (1982), who considered that sexual inversion occurs between ages 2 to 6.

This study recorded a long spawning period, between May and November, with a peak in the summer months, while the resting period is mainly during the winter months. A reproductive season occurring mostly during the summer period had already been described for the Mediterranean and the Western Sahara, while in the Canary Islands the reproductive period seems to occur mostly during the winter, from October to March with a peak in December and January (Table 3).

In Portugal, present legislation stipulates a minimum legal landing size of 18 cm for the axillary seabream. Given the estimated lengths at first maturity of 18.1 cm for males and 17.6 cm for females, this regulation may not be appropriate and the minimum landing size should be increased as a precautionary measure.

ACKNOWLEDGMENTS

This work was funded in part by the European Union (DG XIV Ref. 98/082).

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(Received: September, 2, 2004. Accepted: January, 28, 2004)