AGE AND GROWTH OF THE RED PORGY, *PAGRUS PAGRUS* (LINNAEUS, 1758) (PISCES: SPARIDAE) IN AZOREAN WATERS

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ARQUIPÉLAGO

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Demersal fish species from the Azores have been studied since 1982 with the aim of stock assessment. This work presents the results from a study concerning the growth of *Pagrus pagrus*, through otolith observation and by length frequency analysis. For the estimation of the parameters of the von Bertalanffy growth function, in length, three methods were used, two direct and one indirect. The otolith rings were directly counted by two procedures: first by reading the whole structure, and secondly by observing a thin transverse section of the otolith. Results from the two procedures coincided with each other. The two direct methods used for estimation of the growth parameters from the hard structures (otoliths): direct calculation and backcalculation gave similar results, $L_t=103.0(1-e^{-0.061(t+1.7)})$ and $L_t=104.6(1-e^{-0.066(t+0.7)})$, respectively. The growth curve, $L_t=102.7(1-e^{-0.067(t+1.0)})$, similar to the previous ones, was obtained in the method of indirect estimation of growth parameters by length frequency analysis through MULTIFAN software. The asymptotic lengths obtained in the previous equations were very large when compared with the maximum observed length ($L_{max\ obs}$ = 71 cm), and with similar studies. This may have resulted from incomplete sampling of the older age classes. The results show that this species has a slower growth and a shorter life span in Azorean waters than that off the east coast of North America.

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As espécies demersais dos Açores têm sido objecto de diversos estudos desde 1982 com vista à avaliação deste recurso. Este trabalho consistiu no estudo do crescimento de uma destas espécies, o *Pagrus pagrus*, através da observação dos otólitos e pela análise de frequências de comprimento. Para a estimação dos parâmetros da curva de crescimento de von Bertalanffy, em comprimento, foram utilizados três métodos, dois directos e um indirecto. A contagem dos anéis dos otólitos efectuou-se por dois processos diferentes: observação dos otólitos inteiros e observação de secções transversais finas. Os resultados de ambos os procedimentos foram coincidentes entre si. Os dois métodos directos usados para estimação dos parâmetros de crescimento a partir das estruturas duras (otólitos): cálculo directo e rectrócalculo, deram resultados semelhantes, $L_t=103.0(1-e^{-0.061(t+1.7)})$, e $L_t=104.6(1-e^{-0.066(t+0.7)})$, respectivamente. A curva de crescimento, $L_t=102.7(1-e^{-0.067(t+1.0)})$, semelhante às anteriores, foi obtida pelo método de estimação indirecta dos parâmetros de crescimento pela análise das frequências de comprimento através do programa MULTIFAN. Em todas as funções obtidas, o valor de crescimento assimptótico foi muito elevado quando comparado com o comprimento máximo observado ($L_{max\ obs}$ = 71 cm), e com outros estudos semelhantes. Este facto poderá ter resultado de uma amostragem

incompleta nas classes etárias mais velhas. Pelos resultados obtidos pode-se afirmar que esta espécie apresenta um crescimento mais lento, e um ciclo de vida mais curto, comparativamente ao verificado no costa leste da América do Norte.

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INTRODUCTION

The red porgy *Pagrus pagrus* (Linnaeus, 1758) in Azorean waters is a bottom dwelling species common from temperate to subtropical habitats. This demersal species has been studied in the Department of Oceanography and Fisheries since 1982, because of their high economic value and also for their vulnerability to fishing. The Azores do not have a continental shelf, and its shallow water is limited to some fishing banks and sea mounts. The Azorean demersal community is very diverse but the intensive fishing has lead to a decrease in stock, in this way endangering the fisheries viability (SILVA et al. 1994).

The red porgy is an economically important species for the fisheries in the Azorean Archipelago. The demersal fisheries include 20 species and there is no specific fishery for *Pagrus pagrus*. It is found at depths ranging from 50 to 150 m and is captured with long-line.

It is important to study these species in order to implement management policies and rational exploitation of the stock. The overall objective of this study was to obtain basic information to fisheries management in the Azorean waters. The specific objective was to investigate if the red porgy can be aged by the number of deposition rings on otoliths and apply different methods of growth analysis such as direct reading and backcalculation, and indirect methods like length-frequency analysis using the MULTIFAN software.

MATERIAL AND METHODS

The data were obtained from a project at the Department of Oceanography and Fisheries (DOF), University of the Azores, Horta, for the study of demersal species in Azorean waters. The fish samples were obtained from monthly sampling of the commercial longline captures and from the catches by the R/V "*Arquipélago*".

Biological sampling

In all specimens the fork length (FL) was measured to the nearest cm below, and sexes macroscopically determined (functional males, functional females, transitionals and immature juveniles). Red porgy sampled ranged from 15 to 63 cm FL (Table 1), which corresponds to the size range of red porgy caught in the longline fisheries.

Otolith collection and processing

Sagittae were collected during the period 1991 to 1993. Altogether, 378 were at our disposal, of which 358 were easy to read. The *sagittae* were removed, cleaned and dried. For age reading they were immersed in alcohol and observed using a binocular microscope (magnification 16x) with transmitted light and an image analysis system (NHI-Image©, v.1.44, on Macintosh® Quadra 800).

The otoliths'radii (OR) were measured using the longest otolith axis. The corresponding radius of each *annulus* is the distance between the nucleus and the beginning of each opaque zone. The larger otoliths were processed in the laboratory by making a thin transverse section placed in polyester resin according to the method described by BEDFORD (1983). After testing the annual periodicity of otolith rings by analysis of marginal increments, the number of rings could

Table 1

Fork length (FL) distributions of the age groups of *P. pagrus* and mean values at each age class and standard deviations (SD).

	Age class (years)													
FL (cm)	1+	2	3	4	5	6	7	8	9	10	11	12	13	N_{FL}
63													1	1
61											1	2		3
59												1		1
58										1	1			2
57											2			2
56									1		1			2
55									1	1				2
54									1					1
53										2				2
52										1	1			2
51										3				3
50										1				1
49									1					1
48									1	1				2
47									4					4
46								3	3					6
45								1						1
44						1	4	1						6
43						2	2							4
42							2							2
41					1	2								3
40						1								1
39				2	1	4								7
38				1	7	1								9
37				2	3	3								8
36				6	12	3								21
35				2	6									8
34				9	8	1								18
33				7	4									11
32			1	8	6									15
31			7	18	5									30
30			6	14	1									21
29			16	16										32
28			9	6										15
27			10	5										15
26			16	6										22
25			13	3										16
24			10	1										11
23		1	6											7
22		4	1											5
21		1	2											3
20	2	2	1											5
19	1	5												6
18	5	1												6
17	8	1												9
16	2													2
15	2													2
FL mean (cm)	17.35	20.13	26.71	30.84	34.81	38.83	43.25	45.40	49.00	52.20	56.83	60.33	63.00	
SD	1.35	1.77	2.60	3.18	2.46	2.77	0.89	0.89	3.74	2.78	2.93	1.16	------	
N	20	15	98	106	54	18	8	5	12	10	6	3	1	356

then be converted into ages. For *Pagrus pagrus*, when these observations were made, the first translucent zone was interpreted as representing the passage of the fish through the second winter.

Analysis of otoliths data

The application of the direct method was based on *sagittae* and fork length (FL) data, under the assumption that ring counts indicate total age (in years). The von Bertalanffy parameters obtained were estimated using the non-linear least squares fitting method of FISHPARM program (SAILA et al. 1988). The von Bertalanffy growth parameters were also estimated by backcalculation using the FL-OR (fork length /otolith radius) relation of the Fraser-Lee method (FRANCIS 1990) (for the calculation of the age-length key). This relationship (FL/OR) was calculated from 355 specimens by geometric regression. The age-length key, was done by direct reading of the otoliths and the mean lengths of each age group were estimated. The von Bertalanffy growth parameters were then estimated through the non-linear least squares fitting method of the FISHPARM program (SAILA et al. 1988).

Collection and analysis of length-frequency data

Length data (measurements done as mentioned before) of the most important commercial fish species of the Azores, collected in several harbours, is available in the Regional Fish Sampling Database Program of DOF. Length data of unsexed red porgy of this database, for the period from January 1987 to December 1993, was selected for this study (total of 3351 individuals). However, a part of these data could not be used directly in the analysis as several monthly samples were composed by only a few specimens. To avoid this problem of insufficient sample size, the data of fish captured during the late autumn and winter months (November to April), when growth is slower, were pooled together. Four samples of pooled six-month length-frequency data, each one with more than 300 specimens, were established by this procedure.

These pooled samples were used to calculate the von Bertalanffy growth parameters (k and L_∞) through the MULTIFAN© software (OTTER RESEARCH 1992), that is being commonly applied to fisheries data (e.g. FOURNIER et al. 1990).

To start MULTIFAN, the results of otolith readings, as well as information from literature, were used. For the initial searches (unstructured samples) the following options were introduced: range of k values from 0.055 to 0.080 (with increments of 0.005); range of annual classes from 11 to 17 years; limits for the first cohort, 15 cm (lower) and 18.7 cm (upper) with a standard deviation of 0.97 cm. The subsequent modified systematic searches were performed in order to actively find the error of the first length (introduced by fishing gear selectivity), as well as to find the standard deviations for the mean length for each age class. For some fish populations, variations in length-at-age is not constant across cohorts. This hypothesis allows the standard deviation of length-at-age to increase or decrease linearly with age. New searches of k values, outside the initial range, were also done after the previous operations.

To obtain the best k and L_∞, parameters, the values of the maximum-likelihood function of each systematic search obtained, were compared trough χ^2 test.

Finally, after obtaining the best fitted k and L_∞, values, the t_0 parameter was calculated by the equation (GULLAND 1971):

$$t_0 = t + \frac{1}{k} \ln \frac{L_\infty - Lt}{L_\infty},$$

where Lt is the length on time t.

RESULTS

Period of *annulus* formation

The periodicity in otolith zonation, through observation of their optical nature with respect to the marginal area and by mean monthly marginal increments, agrees with the hypothesis of annual formation (Fig. 1).

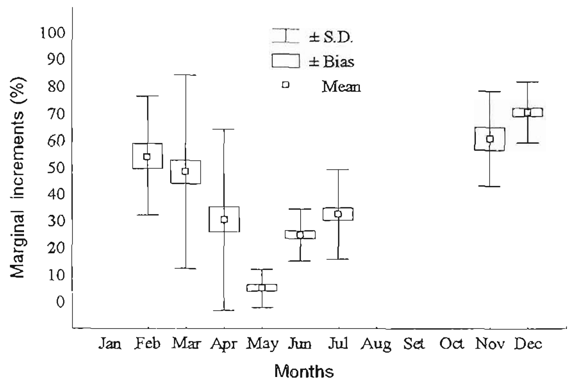

Fig. 1. Mean monthly marginal increments (%). S.D.- standard deviation; Bias = standard error.

The mean marginal increments were highest in February, November and December. In March to May the mean marginal increments were very low. Thus, the opaque edges were formed from early March and late May in each year (Fig. 1). This agree with an annual periodicity of the growth zone formation.

Growth in length

Growth analysis based on otoliths-ring count

The von Bertalanffy model was fitted to the aggregate otoliths-ring count data for relative age classes 2-11. The data for the relative age class 1 were excluded because they corresponded to fish with more than one year of age. This is associated with bias due to selectivity of the gear. The data for relative age classes 12 and 13 were excluded due to their small sample size. From these data the von Bertalanffy growth parameters were obtained (Table 2).

The predominance of females was observed in younger length classes while males reached greater length classes.

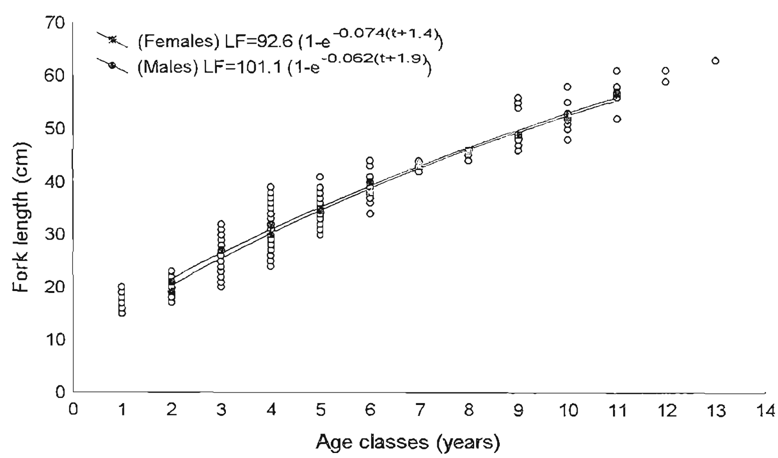

Fig. 2. The Von Bertalanffy curve fitted to males and females.

The covariance analysis (ANCOVA) (SOKAL & ROHLF 1981) detected no significant differences between sexes in growth parameters. The backcalculated age-length key is presented in Table 3. From these, the estimated growth parameters of von Bertalanffy equation are presented in Table 4.

The von Bertalanffy parameters were estimated for each sex (males and females) (Fig. 2).

Growth analysis based on length-frequencies

The best options of the model structure chosen for the red porgy length frequency data set included age dependent standard deviation in length at age and first length bias. The analysis included 50 length classes. Parameter estimates of the means and standard deviations of length at age are given in Table 5.

Table 2

Growth parameters, standard deviation (SD) and coefficient of variation (CV), based upon direct reading of otoliths.

Parameters estimates		SD	CV
L_∞	103.0 cm	0.186	0.18%
k	0.061 $year^{-1}$	0.018	29.5%
t_0	-1.7 year	0.458	-26.9%

Table 3

Mean length obtained by backcalculation, mean values at each age class and standard deviations (SD).

Number of rings / **Age class**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	10.95											
2	10.73	16.92										
3	11.23	17.78	23.64									
4	11.31	17.63	23.09	28.55								
5	10.96	17.18	22.59	27.98	33.43							
6	10.93	17.47	22.76	27.86	32.95	37.59						
7	11.00	17.30	22.53	27.38	32.25	36.73	41.12					
8	11.62	17.82	23.41	28.20	32.60	36.97	40.63	44.61				
9	11.34	18.29	23.44	28.68	33.10	37.00	41.07	44.60	47.88			
10	11.19	18.59	23.30	28.74	33.45	37.71	42.15	44.85	48.27	51.33		
11	11.64	18.23	23.92	29.36	34.56	38.87	42.44	46.47	50.14	53.38	56.20	
12	11.36	19.40	25.34	30.15	34.79	38.92	42.00	45.64	48.90	53.38	55.91	59.86
13	10.80	17.81	23.62	29.13	33.46	38.32	43.36	46.77	50.50	54.31	58.10	59.81
FL mean (cm)	11.16	17.87	23.42	28.60	33.40	37.76	41.82	45.49	49.14	53.10	56.74	59.83
SD	0.29	0.68	0.78	0.80	0.83	0.86	0.95	0.96	1.14	1.26	1.19	0.04
N	355	336	321	223	117	63	45	37	32	20	10	4

Table 4

Growth parameters, standard deviation (SD), coefficient of variation (CV), based on mean backcalculated lengths.

Parameter estimates		SD	CV
L_∞	104.6 cm	0.050	0.05%
k	0.066 year^{-1}	0.005	7.6%
t_0	-0.7 year	0.09	-12.9%

In the period analysed (1987-1993), the best fit corresponded to the age classes 12 and 14 for k values 0.067 and 0.072, respectively. For a k value of 0.067 (age class 12) the model, when four parameters are added, gives a value of 27.35, which represents the double of what was obtained for the model of age class of 11 years. On the other hand and with the same number of parameters added, there are an increase of 43.07 in the maximum-likelihood function, when the age class of 14 years (k=0.072) is considered in relation to the model age class of 13 years.

The $\chi 2$ test, with four degrees of freedom and probability level 0.90, gives a value of 7.78, which means the both models should be accepted as significant, neither being rejected. However, the model with 12 age classes was selected as the best fit due to its low value of the maximum-likelihood function.

Table 5

Von Bertalanffy parameters, k, L_∞ & t_0, mean fork lengths (FL), standard deviations (SD) at each age class in the period considered.

L_∞	K (year^{-1})	t_0	N	r^2
102.7	0.067	-0.96	2126	0.99

Age class (years)	Mean FL (cm)	SD (cm)
1	-------	------
2	18.52	1.88
3	24.00	1.73
4	29.11	1.61
5	33.90	1.50
6	38.37	1.40
7	42.56	1.31
8	46.47	1.24
9	50.13	1.17
10	53.54	1.12
11	56.74	1.06
12	59.73	1.02
13	62.53	0.98

The predicted aggregate length frequency distribution fitted the observed distribution very well over the entire range of size (Fig. 3) and the predicted mode closely matched the actual modes

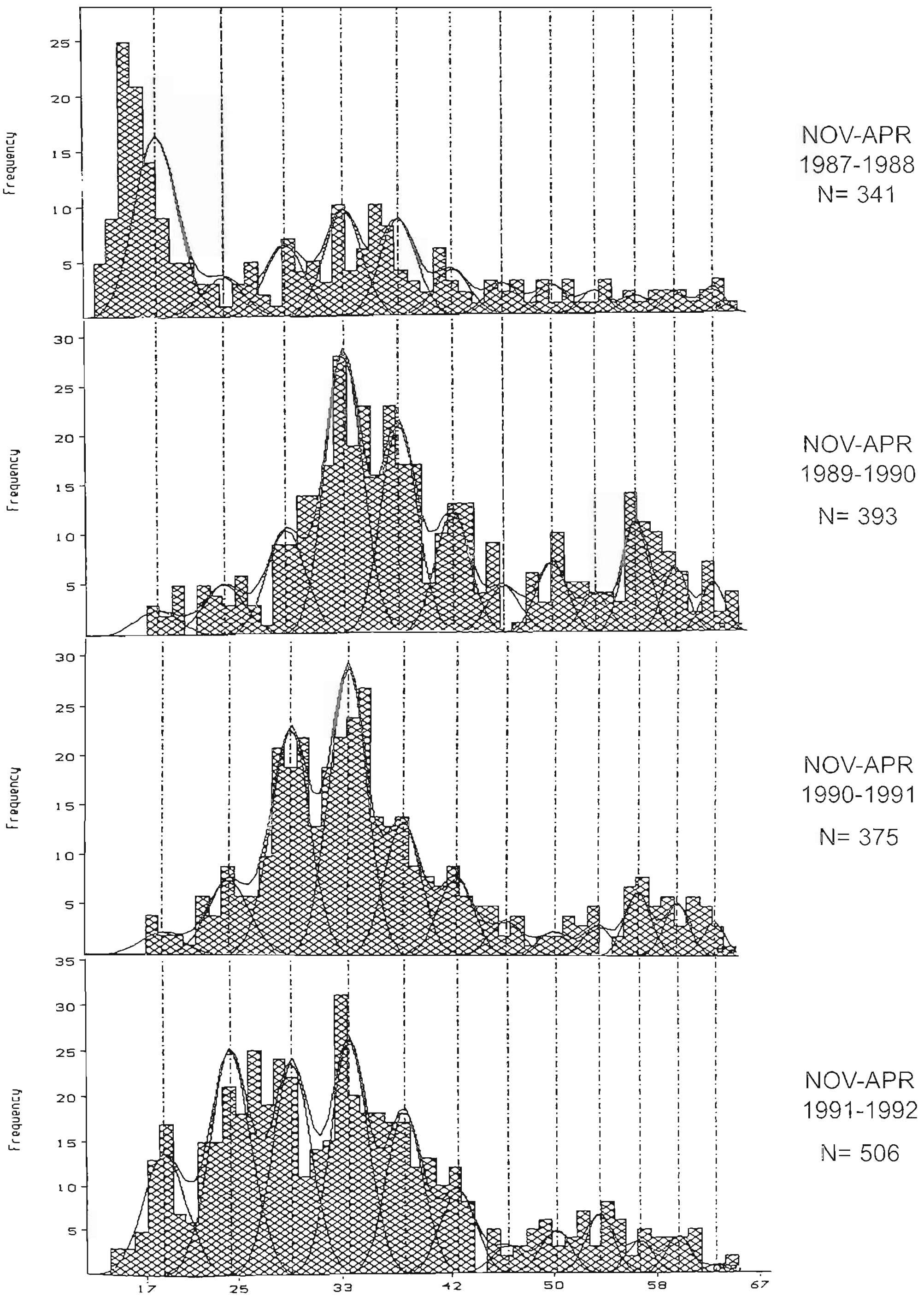

Fig. 3. The result of the best fit of MULTIFAN, for *P. pagrus* length-frequency data set, where the vertical lines represent the estimated mean length of these age classes.

in the four groups of samples pooled by six months intervals, which correspond to the lowest period of species growth (Nov-Apr). The predicted modal distribution pattern indicates that there were usually 12 predominant age classes in the longline catch sample.

Comparison of growth curves

The comparison of the von Bertalanffy growth curves estimated from length-frequencies, by direct reading of otoliths and by backcalculation, were similar (Fig. 4).

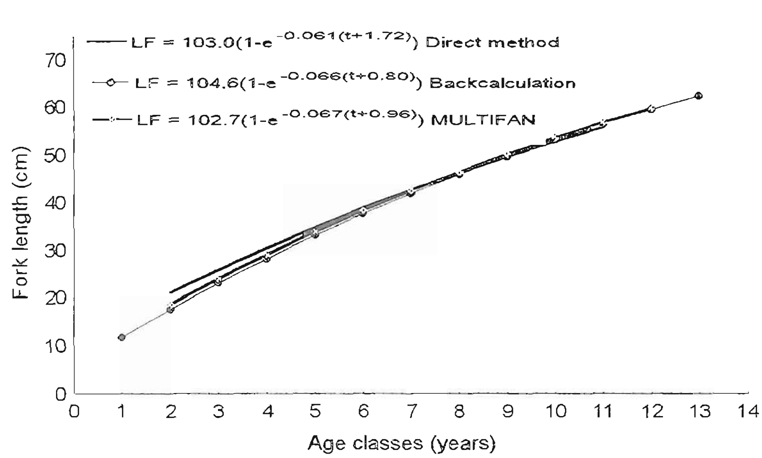

Fig. 4. The Von Bertalanffy curves fitted by three different methods..

In spite of substantial differences in the L_∞ and k estimates, covariance analysis (ANCOVA) (SOKAL & ROHLF 1981) was applied and then compared to the slope of three growth functions. These results indicate that growth curve estimates are significantly similar for F (2,31) with $p<0.05$. The utilisation of the Newman-Keuls test (SOKAL & ROHLF 1981) allows the pairwise comparation of mean FL for the three methods, showing difference in MULTIFAN for $p<0.05$ (Table 6).

Growth in weight

From the length(cm)-weight(g) relation, the following function was estimated:

$$W_t = 0.22 \cdot FL^{0.33} \qquad (r^2=0.98)$$

Replacing the L_∞ in the length function by W_∞, the following equation was derived for the growth in weight using the direct method (otolith reading).

$$W_t = 26.72\left(1-e^{-0.061\ (t+1.7)}\right)^{3.03}$$

DISCUSSION

From this study one can assume that the otolith (*sagitta*) age reading is a valid method due to the alternate formation of opaque and translucent bands in each year. The results of the three different methods of analysis were similar. Growth parameters were estimated by MANOOCH & HUNTSMAN (1977) and ROUMILLAT & WALTZ (1993) from catches, off the North Carolina coast and the south-eastern coast of North America, respectively (Fig. 5). MANOOCH & HUNTSMAN (1977), considered that k was overestimated and that L_∞ was underestimated because they were estimated by backcalculation using the number of rings on scales (k=0.096; L_∞=76.3 cm; t0=-1.88) and they found one 74 cm individual. ROUMILLAT & WALTZ (1993) based his calculation on otolith reading but did not present growth parameters, only mean lengths at

Table 6

Covariance test (Newman-Keuls) for the analysed methods

	back-calculation	direct reading	MULTIFAN
	40.03	39.80	42.98
back-calculation	----	0.860	0.025*
direct reading	0.860	----	0.590
MULTIFAN	0.025*	0.590	----

*- significant a p<0.05.

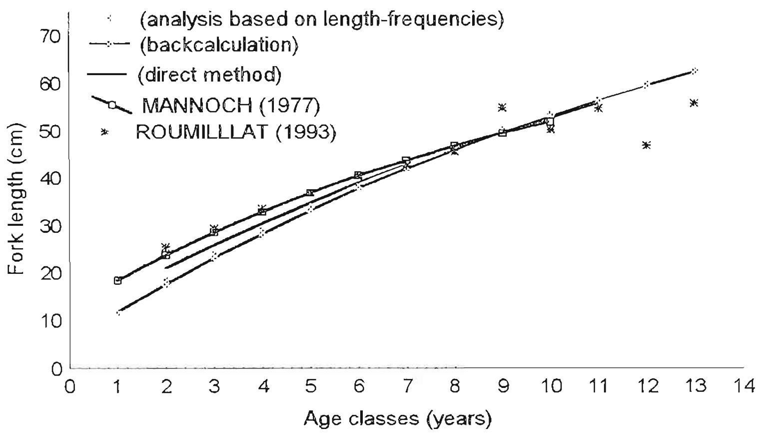

Fig. 5. Growth curves obtained compared with other authors.

different age classes, as shown in figure 5. The largest individual was 55.7 cm in total length (TL).

The predominance of females in younger length classes while males reach greater length classes is in agreement with the sexual characteristic of the species (MANOOCH 1976; MANOOCH & HUNTSMAN 1977; ROUMILLART & WARTZ 1993; VAUGHAN et al. 1992).

The growth of red porgy in the Azores is slower than their equivalents of the American Atlantic coast. For the asymptotic length ($L\infty$) the population of the Azores has generally larger values than those found on the Atlantic coast of North America, but this parameter can be influenced by the number of observed age classes and by the sampling of older age classes, since the absence of older individuals can cause the overestimation of this parameter.

Although it was not possible to determine the age boundaries in the Azorean population, it is clear that this species has a slow growth and short lifespan. In this analysis 13 age classes were observed while MANOOCH & HUNTSMAN (1977) observed 15 age classes in U.S. waters.

The largest specimen captured from this study was 71 cm FL, a big difference when compared to the maximum length $L\infty$ estimates. This fact can be explained by the bias in subsampling older age classes, which can lead to an overestimation of the $L\infty$. Another important fact is related to a possible overestimation of the otolith reading in the age class of more than 7 years.

Despite this conclusion, the results should be considered with some caution, mainly because of undersampling in the younger (0-1 age class) and older age classes (over 9 years). An interesting study in this line of work would be the growth of young specimens in captivity, since their capture in the fishery is limited, caused by the selectivity of the gear.

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