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Age and growth of the southern blue whiting *Micromesistius australis* in the SW Atlantic*

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SUMMARY: Age and growth of southern blue whiting *Micromesistius australis* are studied. Sagitta otoliths from 3650 specimens were used for age determination. These were taken during research surveys and commercial catches in the South West Atlantic during 1994 and 1995. The size of fishes ranged from 17 to 60 cm total length, corresponding to ages 0 to 23 years. Females attained a greater asymptotic length (L_∞ 59.74 cm) than males (L_∞ 54.72 cm). Comparison of growth curves by the likelihood ratio showed that the differences among females and males were due to the asymptotic length, while the other parameters (K and t_0) were not statistically different. The mean weight-at-age, mean length-at-age, and total mortality (Z) were estimated. Growth parameters estimated by sex in the period 1994-95, mean size per age group, and the number of individuals per age in the catches show differences with those calculated when the population was in the early stage of exploitation. A predominance of 2 to 9 year old individuals was observed in the total catches in 1994-1995, whereas in the beginning of the fisheries total catches were basically fish 15 to 19 years old.

Key words: *Micromesistius australis*, age, growth, population-age structure, Southwest Atlantic.

INTRODUCTION

Micromesistius australis (Pisces, Gadidae) is a demersal-pelagic species typical of the cold Malvinas Current. From 38°S to 47°S, it inhabits mostly the continental slope at depths of 100-700 m. From 47°S to 55°S, it is distributed within the Patagonian continental shelf. It has also been caught in Antarctica, the Scotia Arc and the Northern area of the Antarctic Peninsula (Fig. 1). It was also found in waters of Southern New Zealand and S.E. Pacific.

The southern blue whiting (SBW) was considered the most abundant pelagic fish inhabiting the South-West Atlantic Ocean (Otero *et al,* 1982; Csirke, 1987; Wöhler *et al,* 1996: Aubone *et al,* 1994) Commercial exploitation of SBW started in the Argentine Sea in the late 70's. Catches increased steadily, reaching 263000 t. Nowadays, the species occupies the third place in the Argentine catches with 80000 t.

At present, the commercial fleet under the Argentine flag is responsible for most of the total catch. Currently, the fishery area is South of 45° to 56°S, with a key area at the E and NE of the Estados Island (Wöhler and Mari, 1996).

Research on age and growth of SBW based on yearly samples in the area corresponding to the Argentine shelf has been carried out so far on a non-

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exploited population. The aim of this research was to study the age changes that could have taken place in the population after 16 years of intensive exploitation. Moreover, we have analyzed the present growth and mortality parameters, as well as the population age structure.

MATERIALS AND METHODS

Samples were collected from research cruises and commercial catches between 45°S and 55°S, from the coast to the continental slope, in the period 1994-95. In the biological samplings, a subsample was taken of 1 fish out of 5 per trawl and size class, recording their individual values in total length (cm), weight (g), sex, maturation stage and otolith extraction.

Age readings were performed on left otolith sagittae from 3650 specimen. Otoliths were placed in resin epoxi and cut throughout the nucleus in transversal sections of 300 u wide, using a Buehler cutter with a diamond blade. Every section was treated by Photo Floo 200 solution (Kodak) and

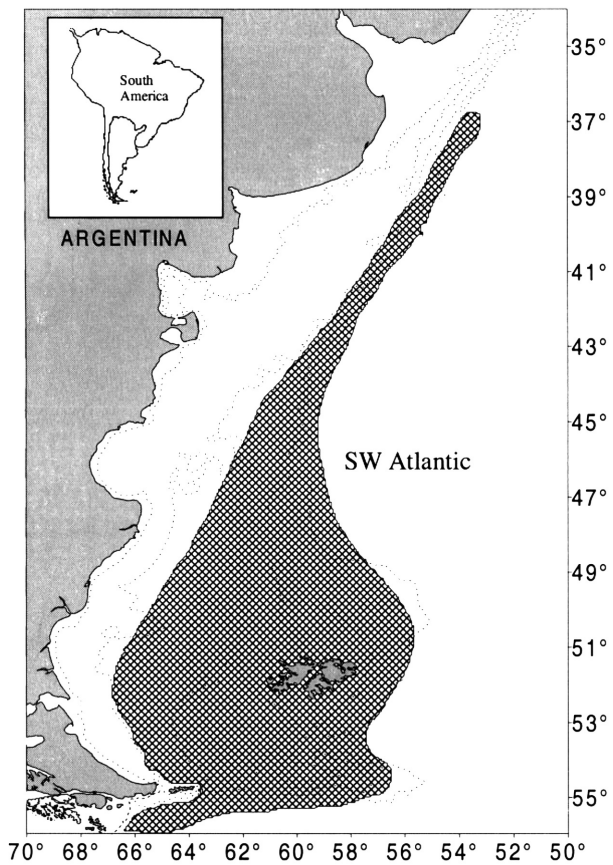

FIG. 1. – Southern blue whiting distribution in the SW Atlantic.

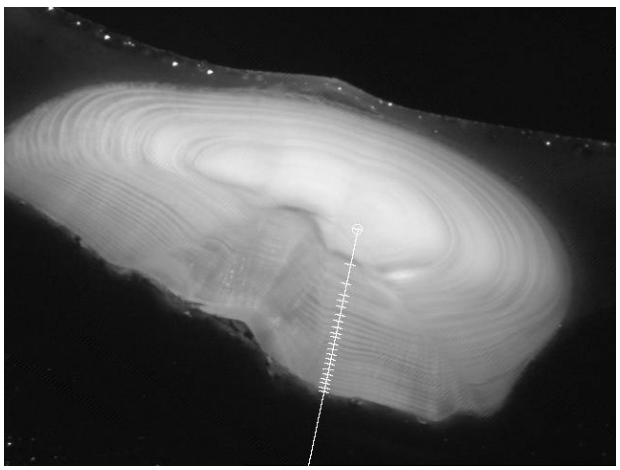

FIG. 2. – Interpretation of age from cross sections of *M. australis* otoliths caught in March 1994 (with annuli indicated). Age estimated as 21 years old, total length 60 cm.

observed with a double beaded Nikon magnifier, under reflected light (Fig. 2). Age estimates were calculated by counting the hyaline rings from the nucleus, along the internal axis, to the edge of the otolith and in the interpretation of the annuli the methodology used by Barrera-Oro and Tomo (1988) was followed.

Growth parameters of the von Bertalanffy model were estimated by the generalized least square method (Kimura, 1980). Comparisons between the growth curves of both sexes were performed using the likelihood ratio (Aubone and Wöhler, 1994). Mean weight-at-age was also recorded. The total mortality rate was estimated by the linearized catch curve.

Catch-at-age of blue whiting in the period 1994-95 was estimated by length/age keys, built from commercial data.

Basic data about SBW growth as provided by Barrera Oro and Tomo (1988) were used to recalculate the growth parameters by using the maximum likelihood method. These parameters corresponding to the time when the exploitation started, were then compared with the current values.

RESULTS

The 3650 fish analyzed had a total length between 17 to 60 cm and an age within the 0 to 23 year range but ages greater than 21 were uncommon. Otolith appearence and structure was reported by Barrera Oro and Tomo (1988) and so the criteria adopted in age determination was the same as those authors. In fish > age 3 years there was no problem

TABLE 1 – Growth parameters and confidence intervals ($\alpha = 0.05$) estimated by maximum likelihood, for the von Bertalanffy model.

SBW	L_∞	C.I.	K	C.I.	t_0	C.I.
Males 79	56.81	56.03-57.66	0.19	0.18-0.21	-2.06	(-2.46)-(-1.72)
Males 94	53.85	52.43-55.46	0.24	0.21-0.26	-0.95	(-1.16)-(-0.89)
Males 95	54.72	52.43-55.46	0.22	0.21-0.26	-0.94	(-1.16)-(-0.89)
Females 79	61.18	60.35-62.02	0.16	0.15-0.17	-2.65	(-3.10)-(-2.25)
Females 94	59.66	58.00-61.66	0.21	0.18-0.24	-1.20	(-1.63)-(0.83)
Females 95	59.74	58.00-61.66	0.19	0.18-0.24	-1.11	(-1.63)-(0.83)

TABLE 2 – Mean length (cm), variance and fish number at age (years) for males and females in 1994

AGE	TLM	VARM	NM	LT F	VARFH	N F
0	15.49	2.35	94			
1	21.88	1.45	16	23.75	6.77	32
2	25.96	12.26	183	28.87	10.75	124
3	32.31	5.43	341	34.36	4.34	321
4	37.67	7.21	156	40.21	6.04	96
5	41.33	4.46	241	43.85	4.54	190
6	44.01	4.52	136	46.60	5.25	111
7	45.82	4.25	130	49.62	4.12	103
8	46.83	3.78	177	50.85	3.41	198
9	48.39	5.10	116	52.09	5.36	110
10	49.25	5.42	91	53.31	4.41	58
11	49.89	5.47	79	53.90	6.43	57
12	50.81	7.72	49	55.11	4.46	46
13	52.44	8.25	32	55.82	5.75	28
14	53.97	8.25	15	57.14	8.38	11
15	54.70	7.15	15	59.80	3.40	10
16	55.75	7.20	12	59.39	3.89	9
17	54.59	11.97	11	61.00	7.80	6
18	54.90	12.61	5	61.50	4.01	2
19	58.83	6.71	3	59.50	4.38	2
20	57.70	7.01	5	62.50	4.20	2

TABLE 3 – Mean length (cm), variance and fish number at age (years) for males and females in 1995.

AGE	TLM	VARM	NM	TL F	VAR F	N F
0	17.00	1.00	1	17.00	1.00	3
1	19.35	0.69	23	20.15	0.24	20
2	24.04	17.18	57	27.97	5.28	33
3	30.68	12.13	203	31.38	11.89	151
4	36.60	3.17	111	37.31	3.73	83
5	40.11	4.15	117	40.88	5.61	93
6	44.01	3.03	30	45.48	2.46	21
7	46.45	2.76	29	47.90	2.53	42
8	47.63	3.29	43	50.38	2.63	37
9	49.04	2.56	24	51.80	2.36	51
10	49.48	2.26	42	52.46	2.35	41
11	50.00	2.67	37	53.52	2.93	25
12	50.64	2.76	28	54.61	3.79	36
13	50.92	3.24	13	56.05	4.55	21
14	53.60	3.82	10	55.72	3.51	18
15	54.67	2.24	15	55.88	9.55	8
16	53.33	2.33	3	58.60	4.30	5
17	54.00	13.60	6	58.50	4.50	2
18	57.00	8.67	4	58.00	1.67	7
19	58.00	0.00	1	59.00	1.00	1
20				58.00	1.00	1

with the interpretation of the annual increment pattern.

Although ckecks often occurred between the first and second annuli these could usually be identified because they were narrower and less distinct than the annuli. On the other hand the first annual ring was validated by the technique of daily ring counts (Cassia and Morioka, 1998). (Fig. 2)

The length/age keys for both sexes were completed using the otolith readings. Later, we calculated mean sizes and variances per age group for the years studied (Tables 2 and 3).

The estimates of growth parameters (von Bertalanffy growth equation) were calculated by means of a maximum likelihood method. In estimating these parameters, we took into account age group 0 to 19 (in males) and 0 to 20 (in females). The resulting curves are illustrated in Figure 3 and Table 1. Growth of fish is fast over the first 6 years reaching 78.10 % asymptotic length in females and 81.72 % in males.

The comparison of growth curves using the likelihood ratio showed significant differences between sexes (Table 1; Fig. 4). Such differences are due to the higher asymptotic length of females, whereas the remaining parameters (K y t_0) did not show statistical differences.

The values of growth parameters corresponding to 1979 are shown in Table 1. The comparison of growth curves using the likelihood ratio (simultaneously comparing the 3 parameters: L_∞, K and t_0) determined that differences are highly significant ($P<<0.01$). When comparing individual parameters they were also highly significant in t_0 ($P<0.01$) whereas the differences in L_∞ and K were not significant ($P=0.2192$ for K and $P=0.0658$ for L_∞).

The relationship between mean weights per age group in catches illustrates that for any given age group females are heavier. The maximum weight was reached at ages 16 years (1080 g) and 17 years (1230 g) for males and females respectively in 1994. Meanwhile, in 1995, the maximum weight

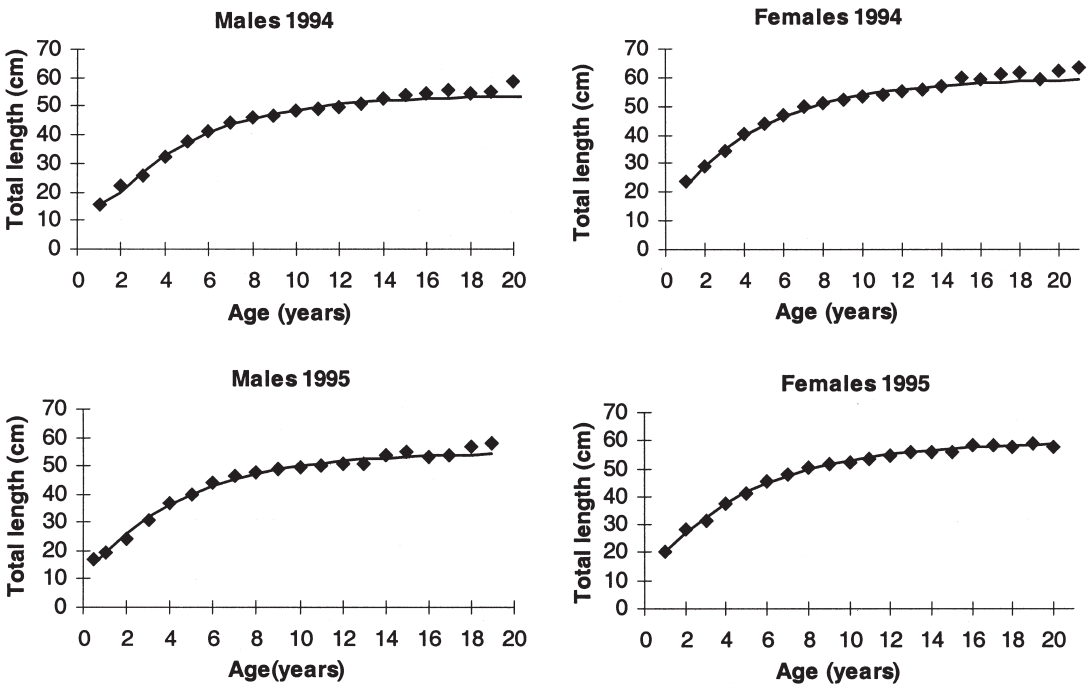

FIG. 3. – Age-growth curves for each sex of *M. australis* in 1994 and 1995.

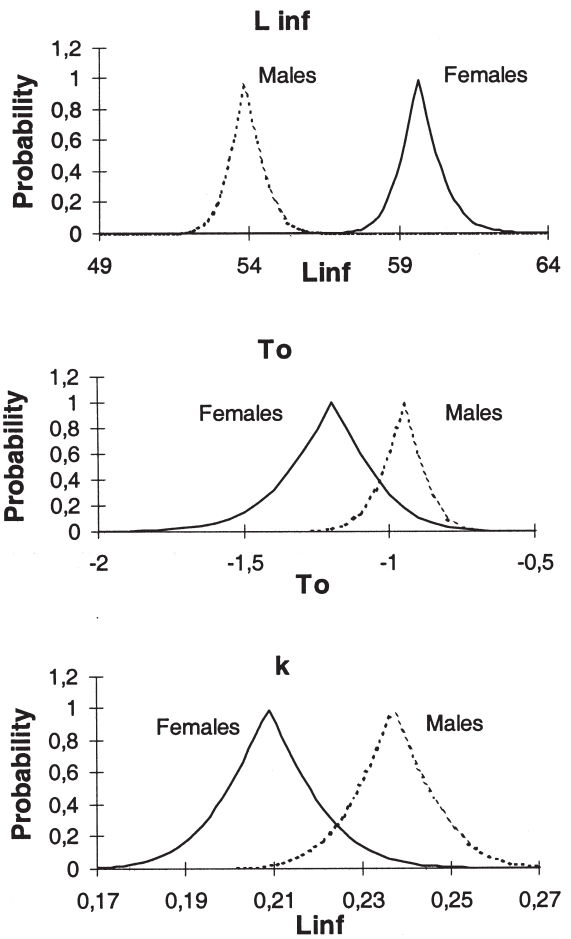

FIG. 4. – Comparison of growth curves by the likelihood ratio of *M. australis* from the SW Atlantic.

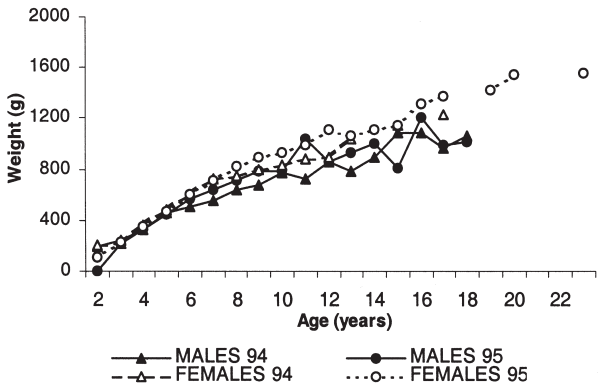

FIG. 5. – Mean weight by age in male and females of *M. australis* during 1994-95 in SW Atlantic.

at those ages was 1210 g and 1375 g respectively. The relationship between age group and weight is observed in Figure 5. In all age groups, females were heavier than males, in both 1994 and 1995.

The estimates of the number of individuals in a distribution per size and age group show that in the period 1994-95 the dominant groups were age 2-9 years. The oldest fish was a female aged 23 years. Length distribution for 1994 presents 3 modes. The mode from 26 to 36 cm corresponded to age 3 years. The mode from 41 to 45 cm represented ages between 5 and 7 years but mainly age 5 years. Finally, the mode from 46 to 57 cm corresponded to an age range of 8 and 17 years, age 8 years being the most abundant (Fig. 6).

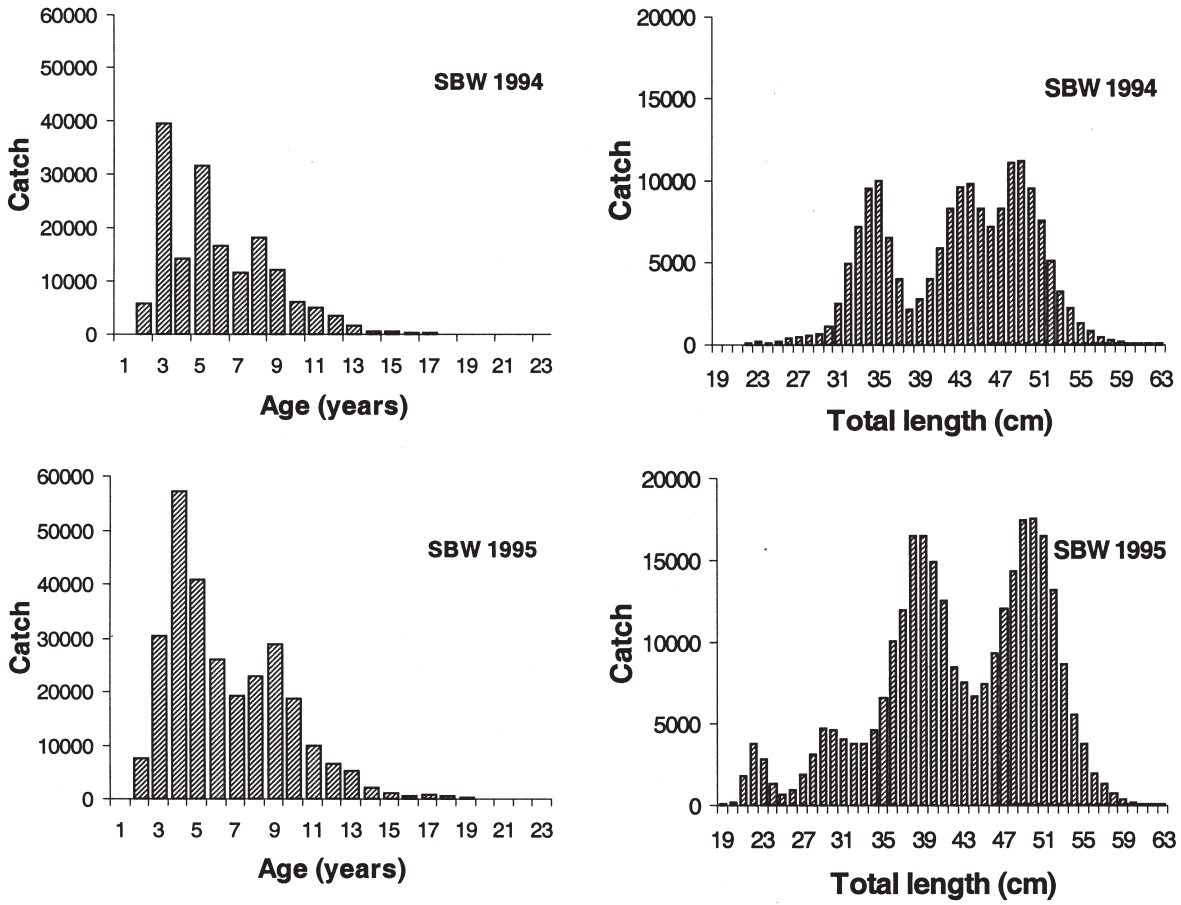

FIG. 6. – Annual catches (in thousands of fish) by age (years) and total length (cm) in 1994-95 from SW Atlantic.

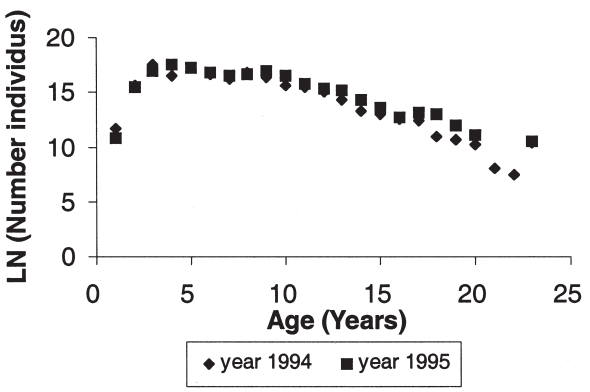

FIG. 7. – Linearized catch curve equation (ages 5-20 years) of *M. australis* from the SW Atlantic.

In 1995, a change in the modes was observed. Most of the catches were between 35 and 45 cm in length (age 4 years being the most abundant) and those from the mode between 46 and 57 cm, age 9 years being most significant (Fig. 6).

Total mortality (Z) for the period 1994-95 was estimated within the age range 5 to 20 years. The regression values of the natural logarithm of the estimates of the number of individuals per age group was 0.44 and 0.38, respectively (Fig. 7).

DISCUSSION

In this study fish size ranged from 17 to 60 cm total length, corresponding to ages 0 to 23 years. Previous studies by different authors showed a difference in the maximum age values when the population was very little exploited. Barrera Oro and Tomo (1988) calculated 23 years, whereas Zukowski and Liwoch (1977) calculated 30 years. In the medium sizes per age group, the maximum differences in age determination occur from 11 years onwards. In a later study, when the population was fully exploited, the maximum ages calculated by Liwoch (1990) were 25 and 24 years. This result is close to the 23 years calculated in the present paper for the period 1994-95. The number of age groups determined for the New Zealand *M. australis* (Hanchet and Uozomi, 1996) was similar to those observed for the *M. australis* of the Southwest Atlantic.

Due to difficulty in the interpretation of the first annulus formation, Barrera Oro and Tomo (1988) applied the back-calculation method, and determined that in the *M. australis* the first annulus formation occurred at 18-23 cm of total length (combined sexes). Later on, Cassia and Morioka (1998) validated the formation of the first yearly ring in *M. australis* juveniles by application of otolith microstructure analysis. The daily ring counts show that the first annual ring formation occurs between 19 and 24 cm TL. This coincides with the mean length observed in this paper.

The statistical comparison of the growth parameters corresponding to two different periods in the history of the population (i.e. at the begining of the exploitation and after an intensive fishing) showed significant differences. In spite of that, there are reasons to belive that those differences arose from the representation of the basic data. The basic data collected by Barrera-Oro and Tomo (1988) would have been biased towards bigger values.

As in many other fish species, females were heavier than males of the same length. Due to the increase of the fishing effort and to the natural extinction of the oldest individuals, the relative abundance of young individuals has increased in catches. Indeed, the estimates of number of individuals per length and age group indicated that in the peak period of exploitation, ages 15 to 19 years with an approximate length of 50 cm, were predominant in the catches (Csirke, 1987). In the period 1994-95, lengths of 26-50 cm and ages 2 to 9 years were the most abundant.

Comparison of our data with previously published values from the same area when the population was in the early stages of exploitation showed an important decrease in the age groups predominant in the catches.

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