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Age and Growth of Redfish (*Sebastes marinus*, *S. mentella* and *S. fasciatus*) in Flemish Cap (Northwest Atlantic)

by

F. Saborido-Rey

Instituto de Investigaciones Marinas, C/ Eduardo Cabello, 6, 36208 Vigo, Spain.
E-mail: fran@iim.csic.es

Abstract

Ageing of redfish is one of the major problems within the research related with redfish. In this paper it is validated the age readings of *S. mentella* in Flemish Cap following the most important year-classes along the last 13 years. The criteria used for *S. mentella* looks consistent and coherent.

Growth of different *S. mentella* cohorts is described and compared observing the existence of a remarkably density-dependence growth in the strong 1990 year-class, which performed a slowest growth rate. This reduction in growth rate has prevented that this cohort become mature at expected age.

Then growth was compared between sexes both in *S. mentella*, *S. marinus* and *S. fasciatus* showing that females grow faster than males. Finally the growth rate is compared among species. *S. marinus* displayed the fastest growth and *S. mentella* the lowest, although the mentioned density-dependence in *S. mentella* has to be considered in the comparison.

Introduction

Age determination of redfish species in the North Atlantic is one of the most important and as yet unresolved questions. There has been controversy concerning the correct method for ageing redfish (Nedreaas, 1990), and several attempts have been made to create a common criterion (ICES, 1983, 1984, 1991, 1996). Although this criterion has not been established yet, an agreement was reached to use exclusively otoliths for redfish ageing.

Russian scientists have read scales under ordinary light (ICES, 1991); German, Danish and Icelandic scientists used scales under polarized light after a silver nitrate treatment (Kosswig, 1980). North Americans use the broken and burnt otolith technique, which is also used by Norwegian scientist (Nedreaas, 1990). Conversely, Spanish scientists use otoliths but with a slightly different technique (Saborido-Rey, 1993). Both Norwegians and Spaniards have used scales routinely in past years. It is necessary to clarify the differences between age readings using scales and otoliths and develop a common procedure among laboratories. It would be useful to develop a conversion factor between otoliths and scales age readings to use a historical data based in scales, which are rather long in some cases. In order to achieve this, age readings must be validated. Common validation techniques include direct methods such as tag/recapture studies (including marking with chemicals such as oxytetracycline, calcein, and others) or the use of known-aged fish; and indirect techniques such as back-calculation, marginal increment analysis, edge progression analysis, frequency-year-class progression analysis, radiometric/isotope analysis, elemental analysis, and others. Direct methods are difficult to implement in *Sebastes* species due to the low survivor when they are caught.

Frequency-year-class progression analysis has been succeeded used in North Atlantic *Sebastes* species: Svalbard *S. mentella* (Nedreaas, 1990) and Gulf of Maine *S. marinus* (Mayo *et al*., 1981)

There are many problems in identifying the redfish species accurately, so in many areas two or more species are considered as a single stock (Saborido-Rey, 1993). This has caused difficulties when comparing growth among species. In Flemish Cap redfish, a previous study was done to validate age readings and to compare growth (Saborido-Rey, 1995). However the short time series available at that time has prevented a correct interpretation of the data that is revised and improved now.

In this study the ages resulting from otoliths are validated through age 10 by following the 1990 *S. mentella* strong year-class over time. Growth of different cohorts of *S. mentella* is analyzed and finally, growth is compared between sexes and species in Flemish Cap bank.

Material and Methods

Since 1988 European Union carried out an annual summer survey in Flemish Cap (Saborido-Rey and Vázquez, 2000). Otoliths have been collected from *S. marinus*, *S. mentella* and *S. fasciatus* during surveys from 1990 to 2000. Sagitta otoliths were removed and preserved in an envelope. Then they were broken through the nucleus, baked in an oven at 200º C for an hour and mounted individually in black plasticine and read under transmitted light. A mixture of 50% of etanol and glycerin was used to clean the surface of the otolith halves. All age readings were made always by the same reader. The numb er of aged otoliths by species, sexes and year is presented in Table 1.

In 1988-89 ages were determined using scales; these data have been not used in the present study. Before 1991 survey, it was not possible to distinguish between *S. mentella* and *S. fasciatus* due to the morphological similarities between them. Therefore only data from 1991 are available for these two species. The age-length keys combined for all the period are shown in tables 2 to 7 for each species and sex.

Due to the difficulties in the identification of the species, the youngest specimens (redfish shorter than 13-15 cm) could not be identified to species routinely and these specimens were grouped in the surveys as redfish juveniles. As stated above *S. mentella* is the most abundant species in the area representing more than 80 % in abundance of the total redfish, except in 1994 survey were an abnormal amount of adult *S. marinus* was caught. Then we can consider that the redfish juvenile group is formed in a high proportion by *S. mentella* specimens. This fact, together with a lack of strong year-class in *S. marinus* and *S. fasciatus*, are the reasons why the validation exercise was made only on *S. mentella*.

To compare growth between sexes and species, data from the 1991 to 2000 surveys were used, except for *S. marinus* where 1990 data also was included in the analysis. The von Bertalanffy growth model was fitted to length at age data using the iterative Quasi-Newton non-linear regression method as implemented in the statistical package *Statistica* (StatSoft, Inc.).

Differences in von Bertalanffy growth curves were tested using Chow test (Chow, 1960). The Chow test is an application of the F-test, commonly used to test for structural change in some or all of the parameters of a regression model. It requires, in the case of two groups, the sum of squared errors from three regressions - one for each group (SS_i) and one for the pooled data (SS_{pool}):

$$Chow = \frac{SS_{within} \; / d.f.}{SS_{error} \big/ d.f.} = \frac{SS_{pool} - \sum SS_i \big/ 3}{\sum SS_i \big/ \sum n_i - 2k} \approx F_{k, n_1+n_2-2k}$$

Results

Age reading validation

Following strong year-classes provides an independent check of age determination in redfish. In the period analyzed here, three year-lasses dominate the length frequency (Fig. 1). 1986 and 1987 year-classes were noticeable since 1988 when survey series started, in 1991 their sizes ranged from 18 to 22 cm, growing to 20-24 cm in 1992 (Fig 1), later they were fished out being difficult to follow them. However, 1990 year-lass (around 8 cm in 1991, Figure 1), was present along the whole period. Over the period analyzed it is possible to identify 10 modal classes between 8 and 27 cm corresponding to 8-9 cm, 12, 15, 17-19, 20, 21-22, 24, 25 and 26-27 cm. The age frequencies derived from otolith readings for the same period are shown in Fig. 2. The age-length keys combined for all the period are shown Table II (females) and III (males). Every year there is an age group dominating the frequency distribution, being one year older with time progression. 8-9 cm modal group is known to be age 1, and in fact during the 1990 survey (not shown in the figure), there was not any modal group smaller than 8 cm. Therefore age frequencies are consistent with length frequencies year to year, and the age assignation can be concluded to be correct, or at least consistent.

To follow properly the evolution in time of the year-class, it should be considered that redfish is totally recruited to gear used in the survey around 15-18 cm but until approximately 20 cm these redfish are not recruited to the fishery. It means that the relative abundance of each age-group increase year by year until around 18 cm, then the abundance drop due to mortality (both natural and fishery mortality)

Growth in *S. mentella*

It can be observed that the 1986 and 1987 year-classes (age 4 and 5 in 1991, Fig 2) showed a higher mean size than the corresponding to 1990 year-class at the same ages, suggesting a different growth pattern for each cohort. Figure 3 show the mean size at age 1 to 10 for the different cohorts of *S. mentella* present during the period analyzed (1985 to 1999 cohorts). At age 1 (Fig 3), mean size was around 9 cm for all the cohorts with less than one cm variation in mean size. At subsequent ages, however, mean size for each cohort shows differences, greater at older ages. The most noticeable observation is that 1990 cohort one of the lowest mean size at all ages, and specially at age 6 to 10, where the difference in size with the precedent cohorts was more than 3 cm (Fig. 3), suggesting a lower growth rate for 1990 cohort.

In general it can be affirmed that cohorts earlier than 1990 (namely 1985-1989) displayed a larger mean size for all ages considered, specially for age older than 6, where these cohorts are well represented (data on aged *S. mentella* are available only from 1991 survey). However for cohorts later than 1990 there is not a so clear common growth pattern. Thus 1992 cohort show one of the highest mean sizes at age 1 to 3, but the lowest at ages 4 and 5. 1994 had the lower mean size at age 3, but at older ages it was around the mean for the 90's cohorts. Generally the mean size for cohorts during 1990's showed a lower mean size than those in the eighties but higher than 1990 cohort.

To illustrate better the growth pattern, in figure 4 is shown the growth trajectories of those cohorts. It can be observed that for all the cohorts there are two stanzas with different growth rates. The decline in growth rate is much more pronounced in 1990 cohort. For this particular cohort, besides, the shift in growth rate occurred at age 5. In 1986-1989 and 1991 cohort the mentioned diminution in growth rate, however, appear at age 6, producing a considerable gap in mean size between cohorts from that age, because these cohorts were growing faster for one year more. Growth rate for 1992 and 1994 cohorts look constant for the period and there are not distinct stanzas.

Growth comparison among sexes and species

The pooled data for each species and sex was fitted to a von Bertalanffy curve (Fig. 5). Table 8 shows the growth equation parameters every fitted curve. Chow test shows than growth was significantly different between sexes ($P<0.001$) in each species (Table 9). The highest difference was shown in *S. marinus* ($F=62.2$) and the lowest in *S. fasciatus* ($F=8.9$). Females grow faster than males in the three species, being more conspicuous in *S. marinus*. The results for *S. fasciatus* should be considered with caution due to the small sample size for large fish, especially in males. Nevertheless, shapes of the curves are similar. Differences in L_∞ are related with differences in size between sexes, biggest are the fish highest is the proportion of females for the three species (Table 10).

T-test were run to evaluate the differences of mean size between sexes at each age, results are shown in Tables 11, 12 and 13 for *S. mentella*, *S. marinus* and *S. fasciatus* respectively. In *S. mentella* differences were significant at $p<0.01$ from age 14 and also at age 2 (Table 11). For *S. marinus* significant differences ($p<0.01$) are present from age 12 (Table 12). And finally, not significant differences occurred at $p<0.01$ in *S. fasciatus*, although at $p<0.05$ differences were present from age 6. The lack of significant differences at older ages in the three species are due to the small number of fish aged, mainly in males, but obviously mean size was also different for these ages, being females always larger than males. In *S. fasciatus* the number of males collected in the surveys drop heavily above age 12 and no males have been sampled above age 16 in the beginning of what seems to be the asymptotic part of the curve.

Growth between species was compared separately in males and females (Table 9). Growth was significantly different in females between the three species, although smaller between *S. mentella* and *S. fasciatus*. In males, significant differences result also in all the three comparisons. The curves were more similar between males than females due to the growth pattern of female *S. marinus*, that showed a considerably highest growth rate than the others curves.

It should be noted that the growth in the three species and sexes was similar until age 15 (the maximum age recorded for *S. fasciatus* was 16), which means more than 98 % of the total redfish caught in the surveys. Nevertheless, females of *S. marinus* show a mean length slightly higher than in the other two species, but this difference is marked from age 13, which account the 1.58 % of the Flemish Cap female redfish population. So most fragment of the redfish population displays a similar growth.

Discussion

S. mentella is the most abundant of the redfish species in Flemish Cap, representing between 80 and 90% of the total number of redfish younger than 10 years in every survey analyzed. Though in the surveys it is not possible to split by species routinely the specimens smaller than approximately 15 cm, it is feasible to argue that those young redfish are mainly composed by *S. mentella*. Frequency year-class progression analysis has been proved to be efficient in other redfish populations (Mayo *et al*., 1981; Nedreaas, 1990). Since 1988, when survey series started, several relative strong year-classes were detected in *S. mentella*: 1980, 1981, 1986, 1987 and 1990.

The first two were two old to follow properly along the survey series. However, during the 1988-1990 surveys an abundant modal group was located from 24 to 30 cm depending of the year (Saborido-Rey, 1995), and they were aged as 9 and 10 years old. Power and Atkinson (1986) reported two strong modal groups in the 1982 Canadian survey on Flemish Cap situated around 12 and 8 cm (1980 and 1981 year-classes). No other strong modal groups appeared neither just before nor just after that year, so it is assumed that those two modal groups correspond with those identified during the EU surveys. The ages assigned to those modal groups can be considered as correct. 1986 and 1987 year-classes were also identified during the EU surveys, but unfortunately their abundance dropt drastically in 1993, making difficult to follow them. However, 1990 year-class (around 8 cm in 1991), was present along the whole period, partially because of its strength and partially because of the decline of fishing effort targeted to redfish in Flemish Cap.

The lack of data of young fish in *S. marinus* and *S. fasciatus* and the fact that no strong year-class of these species were present during the period analyzed has prevented us to validate properly the age determination in these species

Results presented here show that the criteria used for age determination is correct for *S. mentella*, having been validated, at least until age 10. For older ages other technique should be used. Taking into account the ecology features of redfish, the most suitable technique would be marginal increment analysis. This technique require seasonal samples in the year (monthly, quarterly…), which it has been not possible in Flemish Cap because in commercial catches it is not possible to distinguish between *S. mentella* and *S. fasciatus*, and even there are confusion with *S. marinus*. Only in the annual summer research surveys carried out in Flemish Cap since 1991, species are properly identified. The problem about distinguishing redfish species (especially *S. mentella* and *S. fasciatus*) is common in Northwestern Atlantic populations and it has not permitted an analysis of the growth in *S. mentella* and *S. fasciatus*.

Growth rate of 1990 cohort was slower than the rest of the cohorts considered, mean size at ages 7-9 were 4 cm less in 1990 cohort. Since 1988, when EU survey started, 1990 cohort has been the strongest year-class. It can be concluded that a density-dependence growth have occurred in this cohort. Population density is known to be one of the major factors affecting growth rate in fish populations (Wooton, 1990). Several authors have studied the density-dependent growth in exploited fish populations in Newfoundland waters, including Flemish Cap cod, reporting an inverse relation between growth rate and cohort abundance (Templeman and Bishop, 1979; Wells, 1983; P.-Gándaras and Zamarro, 1990). The density-dependence occurs in early years (Shepherd and Cushing, 1980) as a response to intracohort competition for a limited food resource. The limited growth rate in earlier years can affect to growth trajectory along the fish life span. Differences in growth rate have been observed, nevertheless, in other cohorts than 1990. Except for 1991 cohort, growth rates of 1990's year-classes were slower than precedent ones. It can hypothesized that some environmental change have occurred affecting growth rate, such as a reduction in food availability, temperature, However, 1991 cohort had grown at the same rate as late-1980's cohorts, in fact in the 2000 survey, the average size of 9 year old fish (1991 cohort) was already larger 10 year old fish (1990 cohort).

In many fish populations, when lifetime growth is measured, it is often observed the existence of stanzas, with sudden changes in growth rate between these stanzas. The most common reported stanzas are that related with larval metamorphosis, with two different growth patterns, pre- and post metamorphosis. Another stanzas very well described are those related with physiological changes (for example in salmon when migrate from salt- to freshwater) or maturation. In redfish has been observed two growth periods around age 5 or 6. It is difficult now to explain this observed shift. We know it is not related with maturation, because age at maturity in *S. mentella* is around age 10 (Saborido-Rey, 1994). Redfish is known to have a pelagic behavior all around the North Atlantic, but in Flemish Cap, it occurs mainly at young ages (Saborido-Rey, 1994). It is probable that at age 5 or 6 *S. mentella* individuals shift to a more demersal behavior, implying also changes in feeding behavior. It seems that in the new situation, growth has been more affected by population density, because growth rate of 1990 cohort declined more rapidly than other cohorts.

In many fish species, it has been reported that the onset of maturity is size dependent. In fish with accelerated growth, age at maturity decrease, i.e. fish becomes mature earlier (Saborido-Rey and Junquera, 1998). In the opposite direction a decelerated growth can produce a delay in maturation (Wootton, 1990). In Flemish Cap *S. mentella* size at maturity has not changed during the period (unpublished data), but as growth of 1990 cohort has been slower, age at maturity is expected to increase. Histological observations of *S. mentella* ovaries shown that most of the 1990 cohort individuals are still immature (unpublished data). Decelerated growth has prevented to this cohort become mature at common age.

The growth rate in each sex in Flemish Cap is significant different in the three species. In another areas of North Atlantic, male and female redfish grow with a similar pattern, but the females live longer (Surkova, 1961; Sandeman, 1961). Sandeman (1969) has also reported a different growth rate for sexes in Flemish Cap, but the analysis was not made in *S. mentella* and *S. fasciatus* separately, so the results were not conclusive. In the areas where *S. mentella* and *S. fasciatus* coexist, it is difficult to compare the growth due to the problem in the identification of such species. The skill acquired during the surveys allows us to identify properly both species routinely. In our analysis there are significant differences in the growth between *S. marinus*, *S. mentella* and *S. fasciatus*. *S. marinus* live longer than another ones and *S. fasciatus* had a shorter life. However, this difference could be biased because of *S. fasciatus* lives where the fishery is higher (Saborido-Rey, 1993).

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Table 1. Number of fish aged in the EU surveys in Flemish Cap since 1990 to 2000.

	Females			Males		
	S. marinus	*S. mentella*	*S. fasciatus*	*S. marinus*	*S. mentella*	*S. fasciatus*
1990	226			242		
1991	188	260	83	274	257	132
1992	288	485	376	350	452	367
1993	187	184	239	216	225	242
1994	307	361	287	320	364	316
1995	381	367	399	459	366	349
1996	510	607	448	554	661	425
1997	196	243	49	223	279	78
1998	24	257	182	27	234	194
1999	314	458	459	369	517	487
2000	88	232	37	70	233	38
Total	2823	3454	2559	3215	3588	2628

Table 2.- Total age distribution by size class for all female *S. mentella* aged in summer during 1990-2000.

Size	Age (yr)																							
(cm)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25+	*n*
11	1																								1
12	9	1																							10
13	25	3																							28
14	14	21	1																						36
15	2	56	7																						65
16		39	37																						76
17		18	69	1																					88
18		2	49	24	5																				80
19		1	60	49	19																				129
20			25	77	30	4																			136
21			4	77	64	15		1																	161
22				92	51	19	4	2																	168
23				29	58	32	11	8																	138
24				8	91	37	22	10	3																171
25					73	56	31	18	6																184
26					16	91	37	27	9																180
27					2	71	68	29	12																182
28					2	27	77	35	16		1	1													159
29						3	58	63	22	2		1													149
30						1	18	72	44	7															142
31							3	16	52	27	12	1	1												112
32								5	28	40	26	12	3	1	1										116
33									14	28	46	14	14	4		1	1	1							123
34								2	5	17	39	36	25	9	4	2	4	2							145
35										8	19	28	19	16	4	6	2	2	2	1	1				108
36									1	2	7	18	20	18	13	9	7	2					1		98
37											6	12	16	29	18	12	14	3	2	1	1			1	115
38										1	2	5	12	13	18	19	11	6	3	1			1		92
39											1		4	7	17	13	18	15	7	1	1				84
40													3	1	7	7	10	11	8	6	5	3	3	2	66
41													1		3	1	5	6	9	10	2	5	3	1	46
42														1	2	2	3	4	6	6		4	3	3	34
43																		2	4		2	1	5	3	17
44																1			1	2		1	2		7
45																			1			3	1	1	6
46																		1			1				2
	51	141	252	357	411	356	329	288	212	132	159	128	118	99	87	73	75	55	43	28	13	17	19	11	3454

Table 3.- Total age distribution by size class for all male S. mentella aged in summer during 1990-2000.

Size	Age (yr)																									
(cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25+	*n*
9	2																									2
11		2																								2
12		34																								34
13		34	1																							35
14		9	29	1																						39
15			48	9																						57
16			54	30																						84
17			23	66																						89
18			6	70	33	14																				123
19				73	63	24																				160
20				27	104	31	4																			166
21				10	62	63	23	1																		159
22					81	57	22	5	5	1																171
23					43	80	29	18	12	1																183
24					8	77	26	26	17	5																159
25						50	50	33	25	7																165
26						18	92	33	25	16																184
27						5	71	50	33	9																168
28							26	92	30	9	1															158
29							5	66	67	19	1		1					1								160
30								28	69	42	8	3	2					1								153
31								4	35	65	28	9	6		3	3	1	2								156
32									2	43	60	31	10	6	2	1	1				2					158
33									5	14	48	40	31	15	8			2								163
34									1	3	17	48	35	24	13	5	3	3	1	1			1	1		156
35											3	21	26	33	28	15	3	3	3	1	1					137
36											1	8	20	37	29	16	17	6	7	1	2	1	1	1	1	148
37												2	6	10	16	15	11	7	7				2	2		78
38													4	5	5	15	12	13	5	1		2		1		63
39												1	3	2	4	3	7	5	5	3						33
40														2	1	2			3	2	2			2	3	17
41																2		1	1	1					3	8
42																		1	2	2	1	1	3			10
43																1						1	1	1		4
44																				1	2					3
45																		1								1
46																									1	1
48																									1	1
	2	79	161	286	394	419	348	356	326	234	167	163	144	134	109	78	55	46	34	13	10	5	8	8	9	3588

Table 4.- Total age distribution by size class for all female S. marinus aged in summer during 1990-2000.

Size	Age (yr)																							
(cm)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25+	*n*
11	1																								1
12	10																								10
13	28	5																							33
14	5	40																							45
15	2	43	8																						53
16	1	58	44	2																					105
17		21	120	10	1																				152
18		2	81	11	3																				97
19			68	60	5																				133
20			20	115	11	4																			150
21			14	121	7	6																			148
22			2	81	34	6	4	1																	128
23			1	37	89	8	5	1																	141
24			1	17	81	18	8	5																	130
25				8	75	44	14	5																	146
26				1	38	79	16	4	1																139
27				1	24	70	25	11					1												132
28					2	43	54	6		1	1														107
29					2	16	73	26	7		2														126
30						3	25	44	23	10		3	1												109
31						1	13	40	40	12	1														107
32								27	42	28	8	2													107
33							1	13	23	32	9	4		1											83
34								6	8	17	19	10	4	1											65
35								4	7	8	16	15	5	2											57
36									1	6	17	12	8	2	1										47
37									2	2	8	10	7	8											37
38										2	4	7	8	8	7	1									37
39									1		4	5	14	6	5										35
40									1	1	3	1	7	6	4	9	3	4							39
41									1		1	3	1	1	1	5	1	1							15
42												2				6	2	2	3		1				16
43													1		1	4	5	1	2		1				15
44											1	1			1		4	1	1						9
45														1			2	2		3			1		9
46															2			3	3	2	2		1		13
47													1	1			1						1		4
48															1	1		2		1	2		1		8
49																			1			2	3	1	7
50																						1	3	2	6
51														1							1		1	2	5
52																				1			2	3	6
53															1						1		1	3	6
54																								1	1
55																								2	2
56																								1	1
57																							1		1
	47	169	359	464	372	298	238	193	157	119	94	75	58	38	24	26	18	16	10	7	8	3	15	15	2823

Table 5.- .- Total age distribution by size class for all male *S. marinus* aged in summer during 1990-2000.

Size	Age (yr)																								
(cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25+	*n*
8	1																									1
10	3																									3
11		2																								2
12		13	1																							14
13		32	5																							37
14		14	47																							61
15		2	81	4																						87
16			69	45	3																					117
17			23	160	4																					187
18			2	92	11	6																				111
19			1	67	58	5																				131
20				14	128	8	3																			153
21				8	131	23	5																			167
22				1	93	49	9	1																		153
23					42	94	14	7	1																	158
24					17	99	24	2	3																	145
25					8	77	51	12	2	1																151
26					2	35	85	19	4		2															147
27					1	10	92	36	7	1		1														148
28					1	2	64	58	18	7	2			1												153
29						1	26	74	25	8	5															139
30							3	42	60	25	1	2	1	1												135
31								5	43	43	20	5	1	1												118
32								1	18	43	26	18	5		1											112
33								1	6	24	28	24	10	5	2		1									101
34								1	5	11	23	30	21	7	3	1	1	1		1						105
35									2	2	14	27	34	9	5											93
36									1	2	7	7	15	18	11	3	2	1	1	1						69
37											2	2	10	9	23	14	4	1								65
38										1		3	9	7	14	5	4	1								44
39												2	4	2	5	7	7	3			1					31
40														2	4	3	6	2	1	5			1			24
41												1			3	3	3	1	1	1						13
42															2	2	1	1	2					1		9
43														1			2		1	4	2	1	1			12
44																	1	2	1	2	1					7
45																			2	1	1			2	1	7
46																					1				2	3
47																								1		1
51																								1		1
	4	63	229	391	499	409	376	259	195	168	130	122	110	63	73	38	32	13	9	15	6	1	2	5	3	3215

Table 6.- Total age distribution by size class for all female *S. fasciatus* aged in summer during 1990-2000.

Size	Age (yr)																						
(cm)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24	25+	*n*
10	3																						3
11	4																						4
12	24	1																					25
13	38	7																					45
14	10	38	3																				51
15	2	56	4																				62
16		68	24	3																			95
17		23	88	11																			122
18		5	118	24	1																		148
19		3	91	88	2																		184
20			34	182	19		1																236
21			10	161	35	5	2																213
22			2	140	63	10	6																221
23				29	115	19	11																174
24				15	116	26	21	4															182
25				4	53	45	21	12															135
26					11	77	22	14	1														125
27					3	53	28	13	6	2													105
28						18	40	16	4	2	2												82
29						5	32	17	9	3	3												69
30						1	11	17	12	7	2	5											55
31							4	16	16	5	6	4		1									52
32								4	14	12	6	5	1		1								43
33								3	3	8	14	1	2	1	1								33
34										8	7	10	4										29
35											5	7	6	2	1	1							22
36										1	1		5	3	2								12
37										1	2		1		1	3		1					9
38													3	3	2	1	1						10
39													1				1	1		1			4
40																1	1				1	1	4
41													2					1					3
42																		1	1				2
	81	201	374	657	418	259	199	116	65	49	48	32	25	10	8	6	3	4	1	1	1	1	2559

Table 7.- Total age distribution by size class for all male *S. fasciatus* aged in summer during 1990-2000

Size	Age (yr)															
(cm)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	*n*
10	1															1
11	6															6
12	30															30
13	39	8	1													48
14	12	44														56
15	4	60	8	1												73
16		57	37	4												98
17		17	121	10												148
18		3	129	39	1	1										173
19		2	108	118	11											239
20			38	190	27	2										257
21			5	192	55	1	7									260
22			2	133	83	24	11	1								254
23				39	135	28	16	4								222
24				8	116	28	7	5								164
25				5	75	50	20	9								159
26					8	68	16	19	1	2						114
27					3	43	23	9	6							84
28					1	21	27	13	3	2						67
29						3	31	25	4	3	3					69
30							3	25	7	2	1	2		1		41
31								5	11	5	5	2	1			29
32									3	7	3	3		1		17
33										1	3	2	1			7
34										1	2	1		1		5
35										1	1			1		3
36										1			1			2
37										1						1
39															1	1
	92	191	449	739	515	269	161	115	35	26	18	10	3	4	1	2628

Table 8.- Parameters of the von Bertalanffy growth equation of the three species of *Sebastes* in Flemish Cap.

	S. marinus		*S. mentella*		*S. fasciatus*	
	Males	Females	Males	Females	Males	Females
L_∞	46.40	58.15	43.24	45.82	40.31	44.04
K	0.104	0.069	0.107	0.096	0.119	0.103
t_0	-0.79	-1.49	-1.07	-1.28	-1.05	-1.19
Maximum age recorded	38	42	34	31	16	32

Table 9.- Results of the Chow test comparing von Bertalanffy growth curves for the three species of redfish in Flemish Cap by sexes. [1] Critical F=5.42 (α=0.001) for all tests. [2] denominator df (numerator df=3 for all comparisons)

Groups compared		F[1]	df[2]
S. marinus	Females-males	62.2	6026
S. mentella	Females-males	16.1	9057
S. fasciatus	Females-males	8.9	5175
Females	*S. marinus - S. mentella*	233.9	7275
	S. marinus - S. fasciatus	86.4	5370
	S. mentella - S. fasciatus	6.1	7011
Males	*S. marinus - S. mentella*	99.7	7814
	S. marinus - S. fasciatus	73.0	5837
	S. mentella - S. fasciatus	6.2	4151

Table 10.- Proportion of sexes by size on each species (data combined 1991-2000).

	S. marinus		*S. mentella*		*S. fasciatus*	
Size	F	M	F	M	F	M
12-14	47.06	52.94	36.94	63.06	48.50	51.50
15-17	47.20	52.80	52.07	47.93	46.34	53.66
18-20	49.23	50.77	43.08	56.92	47.96	52.04
21-23	46.57	53.43	45.95	54.05	48.18	51.82
24-26	47.84	52.16	52.60	47.40	48.84	51.16
27-29	46.04	53.96	45.60	54.40	50.60	49.40
30-32	45.68	54.32	44.50	55.50	56.90	43.10
33-35	37.39	62.61	45.81	54.19	82.72	17.28
36-38	37.02	62.98	52.95	47.05	90.00	10.00
39-41	51.14	48.86	79.31	20.69	90.91	9.09
42-44	59.52	40.48	81.16	18.84	100.00	0.00
45-47	60.00	40.00	88.89	11.11		
48-50	100.00	0.00				
51-53	94.12	5.88				
54-57	100.00	0.00				
Total	46.67	53.33	49.27	50.73	49.96	50.04

Table 11.- Results of the t-test to evaluate the differences in means between sexes for each age in S. mentella in Flemish Cap. * Significative at $p<0.05$ ** Significative at $p<0.01$.

	Males		Females			
Age	Mean	*n*	Mean	*n*	*t*	
2	12.7	80	13.1	51	-3.17	**
3	15.6	176	15.5	154	0.95	
4	18.2	351	18.1	296	1.02	
5	20.9	476	20.9	434	0.00	
6	23.4	352	23.6	391	-1.31	
7	25.8	423	25.8	401	-0.51	
8	27.0	508	27.1	438	-0.67	
9	28.1	430	28.1	375	-0.18	
10	29.9	327	29.9	290	0.23	
11	31.7	255	31.9	193	-1.05	
12	33.1	226	33.4	222	-1.36	
13	34.1	208	34.3	204	-0.87	
14	34.8	190	35.4	173	-2.66	**
15	35.5	159	36.2	155	-3.74	**
16	36.3	106	37.4	126	-4.00	**
17	36.9	82	37.9	102	-3.54	**
18	36.8	68	38.1	97	-3.67	**
19	37.9	47	39.1	80	-3.33	**
20	38.9	21	40.3	58	-2.37	*
21	38.7	16	40.3	46	-2.19	*
22	40.0	9	40.6	27	-0.71	
23	39.8	13	41.3	35	-2.31	*
24	39.0	9	41.6	25	-3.81	**
25	40.1	7	41.6	18	-1.50	

Table 12.- Results of the t-test to evaluate the differences in means between sexes for each age in *S. marinus* in Flemish Cap. * Significative at $p<0.05$ ** Significative at $p<0.01$.

	Males		Females			
	Mean	*n*	Mean	*n*	*t*	
2	13.0	47	13.0	63	-0.10	
3	15.3	169	15.3	229	0.44	
4	17.8	359	17.6	391	1.90	
5	20.9	499	20.9	464	0.95	
6	23.6	409	23.9	372	-2.46	*
7	26.2	376	26.1	298	0.76	
8	28.1	259	27.9	238	0.99	
9	30.0	195	30.1	193	-0.47	
10	31.5	168	31.9	157	-2.16	*
11	32.7	130	32.9	119	-0.65	
12	33.9	122	35.1	94	-3.92	**
13	35.1	110	36.1	75	-2.88	**
14	35.8	63	37.5	58	-3.62	**
15	37.2	73	38.6	38	-2.80	**
16	38.2	38	40.8	24	-3.49	**
17	39.0	32	41.3	26	-4.11	**
18	39.5	13	42.9	18	-4.05	**
19	42.0	9	43.5	16	-1.26	
20	41.1	15	44.3	10	-2.84	**
21	43.3	6	46.7	7	-2.43	*
22	43.0	1	47.1	8	-1.05	
23	41.5	2	49.3	3	-6.54	**
24	46.0	3	49.1	11	-1.59	
25	46.0	2	52.0	4	-2.31	

Table 13.- Results of the t-test to evaluate the differences in means between sexes for each age in *S. fasciatus* in Flemish Cap. * Significative at $p<0.05$ ** Significative at $p<0.01$.

	Males		Females			
Age	Mean	*n*	Mean	*n*	*t*	
2	12.7	92	12.7	81	0.42	
3	15.3	191	15.4	201	-1.49	
4	18.0	449	18.1	374	-1.54	
5	20.5	739	20.6	657	-1.65	
6	23.0	515	23.2	419	-2.08	*
7	25.2	269	25.6	259	-2.43	*
8	26.1	161	26.7	199	-2.10	*
9	27.7	115	28.3	116	-1.97	*
10	29.6	35	30.2	65	-1.77	
11	31.1	26	31.7	49	-1.09	
12	31.4	19	32.6	48	-2.19	*
13	31.8	10	32.9	32	-1.72	
14	33.3	3	35.8	25	-1.77	
15	32.8	4	34.7	11	-1.01	
16	33.5	2	35.6	8	-0.78	

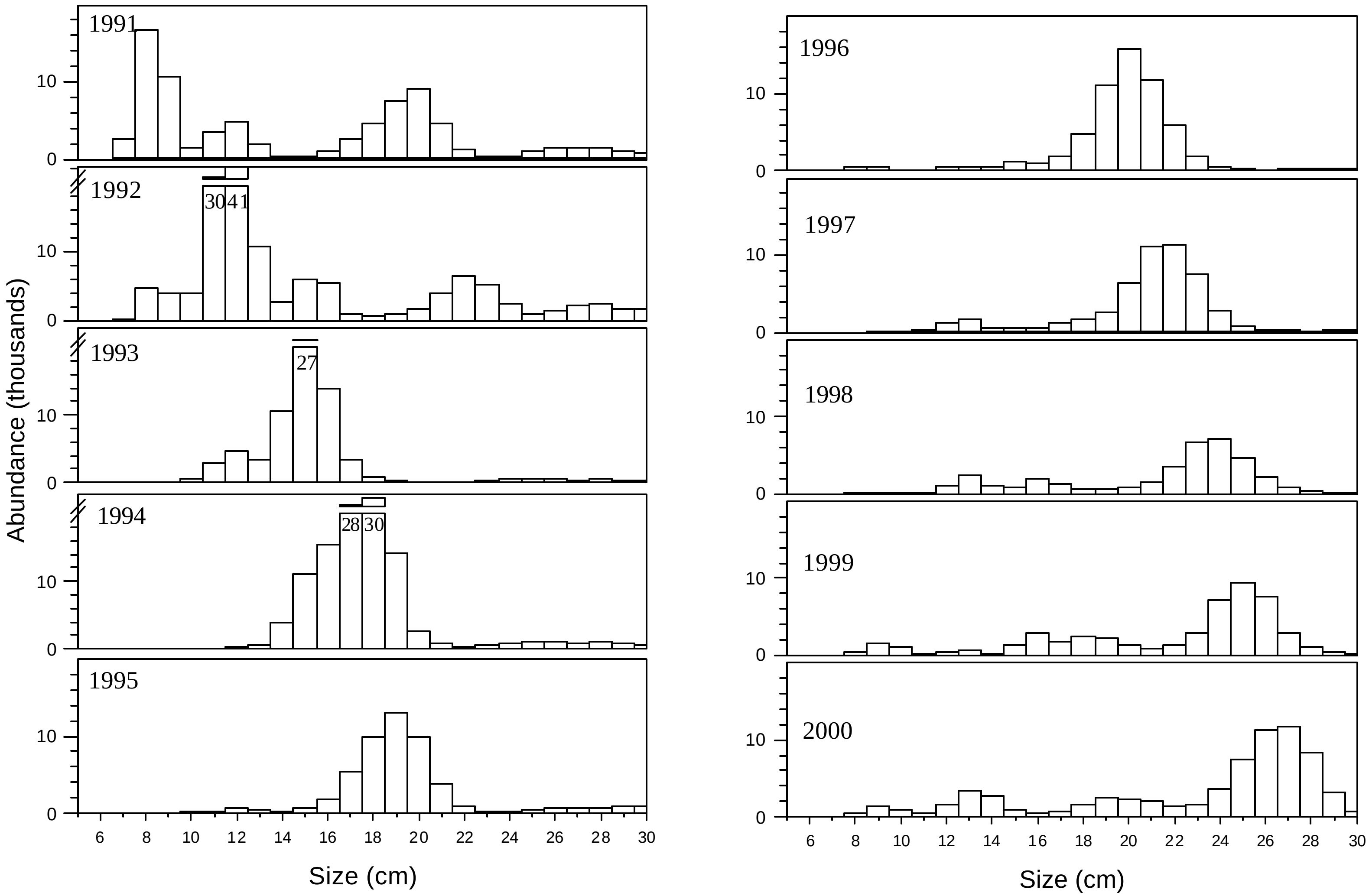

Figure 1. - Length frequency (up to 30 cm) of redfish on Flemish Cap in the period 1991-2000.

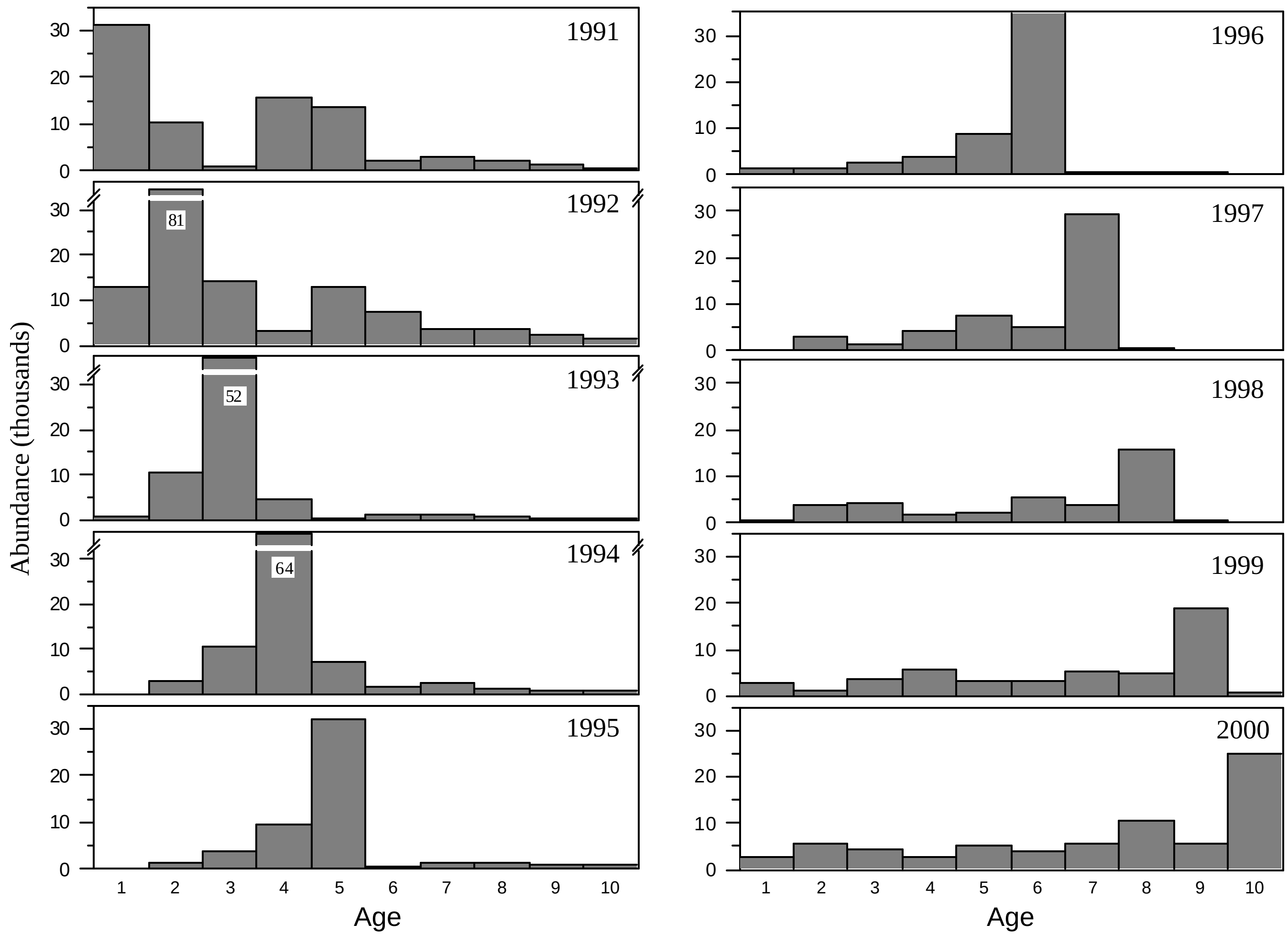

Figure 2. - Age frequency (up to age 10) of redfish in Flemish Cap in the period 1991-2000

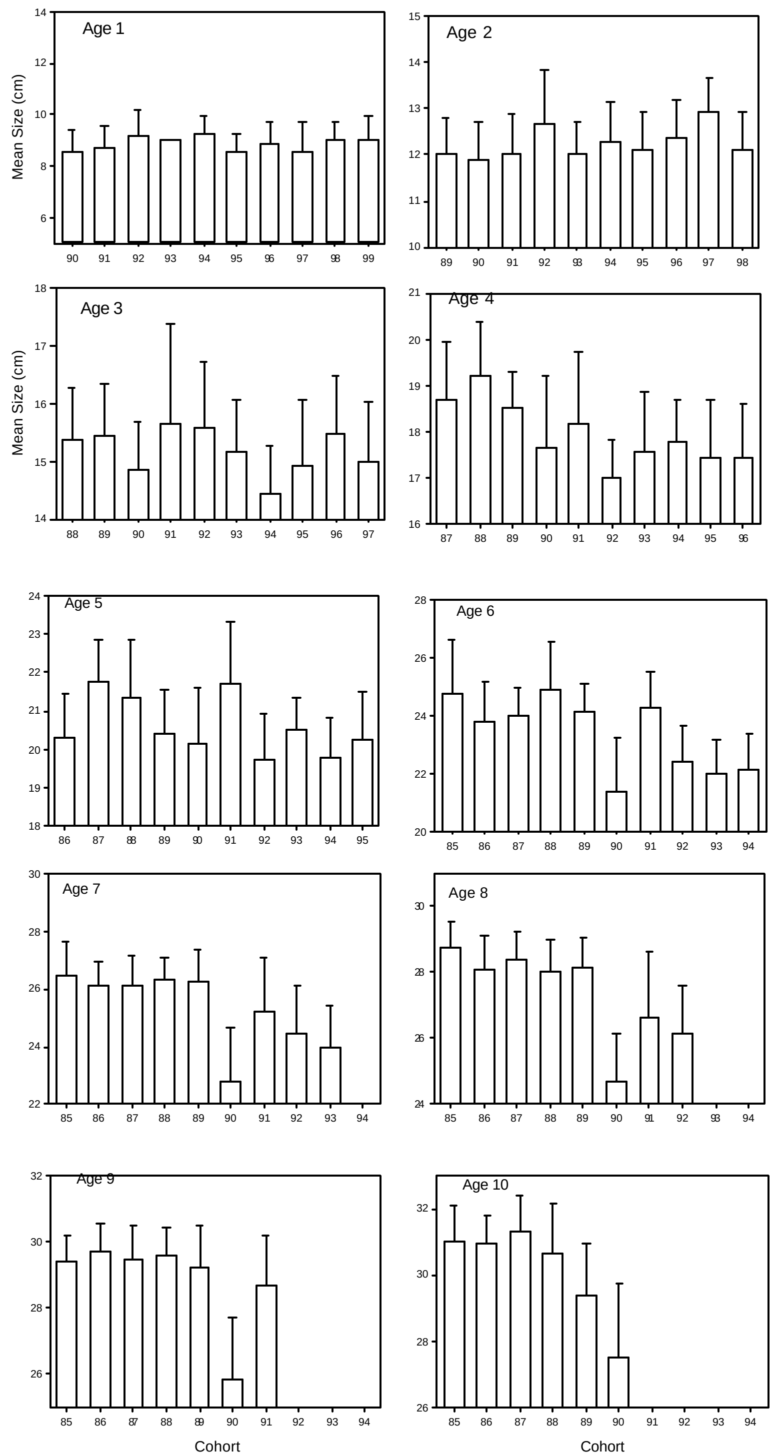

Figure 3. – Mean size at age for each cohort and age in Flemish Cap *S. mentella*.

Figure 4. Growth trajectory for different cohorts of *S. mentella* in Flemish Cap (Growth represented as mean size at age).

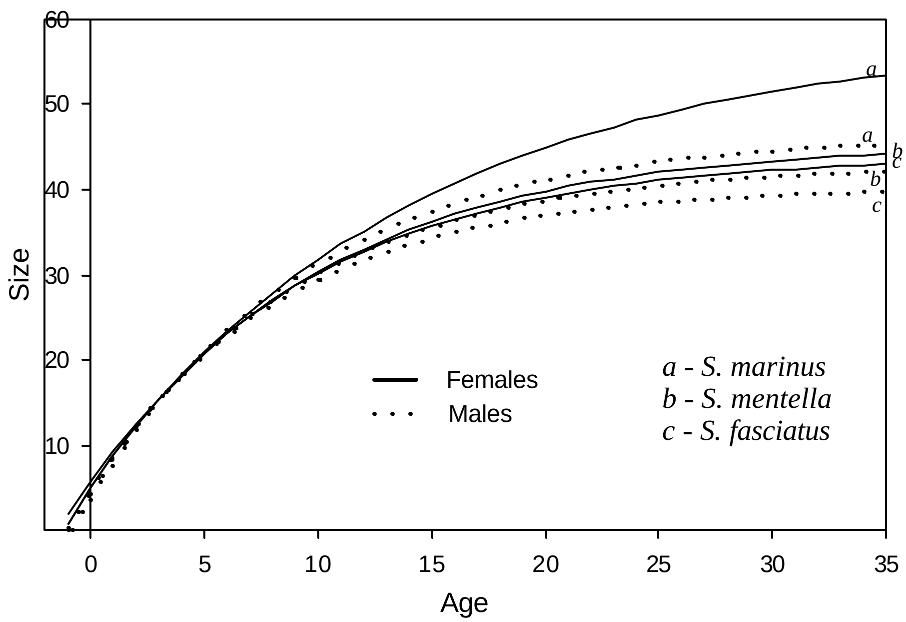

Figure 5.- Growth curves fitted to von Bertalanffy equation for the three species of redfish in Flemish Cap.