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A Review on Roughhead Grenadier (*Macrourus berglax*) Biology and Population Structure on Flemish Cap (NAFO Division 3M) 1991-2003 Based Upon EU Flemish Cap Bottom Survey Data

by

H. Murua[1] and F. Gónzalez[2]

[1]AZTI Foundation, Herrera Kaia, Portualde z/g, 20 110 Pasaia, Spain. E-mail: hmurua@pas.azti.es
[2] Instituto Español de Oceanografía, Vigo, Spain. E-mai: fernando.gonzalez@vi.ieo.es

ABSTRACT

The European Union has conducted since 1988 an annual bottom trawl survey in Flemish Cap (NAFO Div. 3M) in the 200-720 m depth range. The information on roughhead grenadier population structure recorded during the last 13 EU surveys (1991-2003) in Flemish Cap is presented. Depth distribution of captures, length/age distribution of captures, growth rates, sex-ratios, catch curves, and total biomass estimated by the swept area method are presented.

Age and length composition of the catches showed clear differences between the two sexes. The importance of males in the capture declines in larger fish, disappearing from the capture in largest length-lasses.

Results show that roughhead grenadier has a prolonged life cycle and multiaged population structure with differences in growth and mortality between males and females.

INTRODUCTION

The roughhead grenadier (*Macrourus berglax* Lacépède, 1802) is an abundant and widespread fish species in the north Atlantic and is usually found both on the shelf and on the continental slope (Scott and Scott, 1988; Savvatimsky, 1994). It is predominant in depths ranging from 400 to 1 200 m, although they may inhabit depths between 200-2 000 m (Snelgrove and Haedrich, 1985; de Cardenas *et al*., 1996). It has, however, been found in depths up to 2700 m (Wheeler, 1969).

Roughhead grenadier is becoming an important commercial fish in NAFO Regulatory Area and reliable information is needed for its assessment. The fishery for roughhead grenadier is unregulated as it has been mainly taken as by-catch in Greenland halibut fishery. Catches of roughhead grenadier increased sharply from 1989 (333 tons) to 1990 (3 244 tons), since then total catches has been about 4 000 tons and increased 7 200 tons in 1998 remaining at this level in 1999. The catches decreased to 3 700 tons in 2002.

Since 1988 EU has conducted an annual random-stratified bottom trawl survey in Flemish Cap (NAFO Div. 3M) in the 200-720 m depth range. The objective of this scientific survey is to obtain abundance indices and to study the population structure and biological parameters of the main species in the area. In 2003, the survey was carried out with a new R/V *Vizconde de Heza*, which replaced the former C/V *Cornide de Saavedra*. In order to maintain the data series, comparative fishing trials were carried out to develop conversion factors for the species sampled. In total, 59 paired hauls with R/V *Cornide se Saavedra* were done. Further, comparative studies will be carried out during July 2004.

Limited information on age structure and growth rate of *M. berglax* is available in scientific literature. Savvatimsky (1971, 1984, 1989, 1994) and Jorgensen (1996) have carried out studies on this species in the NW Atlantic (NAFO Div. 0, 2GHJ, 3K and 1ABCD respectively), basing findings on age readings from scales. The age structure and growth parameters of roughhead grenadier have been estimated by Murua (2003) from otolith readings of specimens captured in NAFO Div. 3LMN. Validation of age estimates derived from otolith reading has been presented by Rodríguez-Marín *et al.* (2002). Eliassen (1983) also performed age estimation by otolith reading from roughhead caught in the continental slope of Norway.

This paper presents some biological data and population structure of roughhead grenadier in Flemish Cap during the period 1991-2003. The results are presented taking into account that the survey only covers the shallowest distribution area of roughhead grenadier.

MATERIAL AND METHODS

Data on roughhead grenadier for the 1991-2003 period were collected on the annual random-stratified bottom trawl surveys carried out by the European Union on the area (Casas, 2004). Data on age structure and sex-ratio are only available for the 1994-2003 period. Otolith sampling began in 1994, and since then a total of 4 805 otoliths have been read. Annual length-age keys have been applied for each year. For years when otoliths were not sampled the mean 96-97 age-length key (the most consistent readings) were applied.

Otoliths were broken through the nucleus and read by transmitted light (Casas, 1994). Many difficulties in reading Macrouridae age from otoliths and scales have been reported previously (Savvatimsky, 1984). Age reading in larger fish (more than 9 years old) is even more complicated, because many rings are present and they lie close to each other. Nevertheless, intercalibration of readings between three readers has been done and 80% of agreement has been reached. Differences were $\pm$1 year in otoliths between 2-10 years and 1, 2 years in older than 10 years (Rodríguez-Marín *et al.*, 2002).

Individuals were measured from tip of snout to base of first anal-fin ray, in 0.5 cm intervals, as adopted by NAFO in June 1980 (Atkinson, 1991) as a standard measurement for roundnose and roughhead grenadiers. Length is presented as pre-anal-fin length (AFL) and data are given in 1 cm intervals. Total weight was recorded accurate to the nearest 10 g.

RESULTS AND DISCUSSION

Total biomass of roughhead grenadier estimated by the swept area method by strata is presented in Table 1 and for the whole bank in Fig. 1. Biomass increased from 1989 to 1993, since then the biomass has decreased steadily, with the exception of 1998 year, up to 2000, and in 2001 total biomass increased again. Biomass decreased in 2002 to the level of 1 440 tons and then increased reaching the second highest level (3 175 tons) of the time series in 2003. Mean catch per trawl by strata and whole bank data are presented in Table 2. The results indicate that roughhead grenadier occupies the deepest part of the area studied and the abundance and biomass increase with depth, as is evidenced by other authors (de Cardenas *et al*., 1996).

Table 3 shows length distributions of roughhead grenadier for the 1991-2003 period. Captures are dominated by the 14-20 cm length-lasses, 51% of the total catch. The average AFL for both sexes is 15.2 cm. This value is smaller than the values found by Savvatimsky (1994) and de Cardenas *et al*. (1996). The former gives an average AFL of 19.8 cm (51.25 cm total length) for Div. 3K, and the latter gives a mean AFL of 21.12 cm (54.39 cm TL) for specimens caught in a long-line survey in Div. 3LMN. These differences are related to the fishing gear employed and depth where fish were caught, because length has a tendency to increase with depth, from the shallowest stratum to the deepest (Cárdenas *et al*., 1996). It should be noted that the proportion of 2-8 length range has increased considerably to around 36% during 2003 surveys, it may be a sign of a good year class recruiting to the population. Moreover, due to this increase the proportion of the 14-20 length range decreased to around 35% in 2003 (Table 3).

Annual length frequencies by sex are presented in Fig. 2. The importance of males in the capture declines in larger fish and they disappear from the capture in largest length-classes. Largest male found in the scientific surveys was 26 cm while females are larger reaching 35 cm long. Average AFL for females is also greater than for males. Female's mean AFL for the 1993-2003 period in Flemish Cap was 16.3 cm, while mean AFL for males was 15.0

cm. This sexual difference is consistent with data found in the literature. Savvatimsky (1989) gives an average AFL of 18 cm (47 cm total length) and 21.2 cm (54.6 cm total length) for males and females respectively in Div. 3LKN. Those differences have also been seen in the commercial fleet in Div. 3LN, where females are larger than males (Junquera *et al*., 2001).

The mean AFL-age key for 1994-2003 is given by sex in Table 4. Table 5 shows age composition by sexes for roughhead grenadier in Flemish Cap in 1993-2003. The oldest male found in the period studied was 20 years old and the oldest female 21 years old. Mean age for females in Flemish Cap in the 1993-2003 period was 7.5 years, while mean age for males was 7.1 years. Savvatimsky (1994) for Div. 0B, 2GH and 3K found similar differences.

Interannual differences in length and age are shown in Fig. 2 and 3. The 1984-1986 cohorts dominated the catches during the first years. The importance of these annual classes has declined sharply during last 4 years and the 1990-91 cohorts now dominate captures, although their importance has declined in 2003. In 2003, more than 20% of the individuals in the survey were composed by individuals of age 2; this 2001 year-class is by far the most abundant year-class at age 2 in the time series.

Female-ratio in the whole study period is 50%. This value is lower that the one found by de Cardenas *et al*. (1996) in Div. 3LMN, where females made up 71.4% of the catch. However, this difference could be explained due to the different area covered by both surveys. As length increases in relation to depth in many species, the 'bigger deeper' distribution (Merrett *et al*., 1991; Gordon and Bergstad, 1992), the female ratio might increase also in the deeper water areas.

Figures 4 and 5 present sex-ratio by age and by length respectively, for the whole study period. In the sex-ratio, female proportion fluctuated around 40%-50% the first 10-12 years (up to 20 cm in length) and increased to 75% at 13 years (22 cm) and 80% at 14 years (24 cm). Following this age, females made up 100% of the catch. Similar sex-ratio, with males being more abundant in the central part of the population, is described by Savvatimsky (1994) for north-western Atlantic.

The increment in the female-ratio can be due to different reasons: sexual differences in growth rate, in mortality or a combination of both. In this case, there are certainly sexual differences in growth, which are reflected in the mean length at age and in the different growth curves presented in this study.

Logarithmic regression lines (Fig. 6), fitted to mean length at age by sex, show that males growth rate declines when reaching 18 cm long, around 9 years old, while females do not decline growing until reaching 34-35 cm, around 20 years old. This result was also observed by Savvatimsky (1994), Jorgensen (1996) and Rodríguez-Marín *et al*. (2002). Moreover, mean length at age for all year studied is similar for males and females for ages under 9 years, but males grow slower from this length onwards. Mean lengths at age are higher than those obtained by Savvatimsky (1994) for NAFO Div. 0B, 2GH and 3K. Savvatimsky (1994) and Jorgensen (1996) described similar growing pattern using scales for ageing fish, they found that the differences between sexes in size at age come about from 10 years onwards. This fact could be explained due to the different ageing method used or due to different latitude of the sampling areas where specimens were obtained, because temperature differences would cause slower growth and a delay in reaching sexual maturity (Rodríguez-Marín *et al*., 2002). Table 6 shows the estimated parameters of the Von Bertalanffy equations (fitting individual length at age by non-linear regression (Marquardt, 1963)) and the equations for logarithmic growth regression curves for all the period studied.

On the other hand, it seems that there are some differences in mortality between both sexes, since males disappear from the capture in larger length-classes. Total mortality by sex was calculated from catch curves, fitting regression lines by sex to ages fully recruited to the fishery, using data of ten years (1994-2003). Both sexes are fully recruited at age 7 and the mortality obtained is different for bots sexes: 0.25 for females and 0.48 for males (Fig. 7).

Length-weight relationships by sex are shown in Table 7 for all the years studied. The relationship between fish length (AFL) and fish weight was assumed to be adequately expresses by the exponential function. Figure 8 shows the length-weight relationship by sexes in 2003 survey.

Data available show that roughhead grenadier has a prolonged life cycle and multiaged population structure with differences in growth and mortality between males and females. The complex multy-mode length structure and a slow growth are characteristic of deepwater fishes, including grenadiers (Hureau *et al*., 1979; Casas, 1994; Savvatimsky, 1994). All this results must be taken with care due to the small proportion of the roughhead grenadier distribution area covered by the survey.

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Table 1.- Total biomass of roughhead grenadier estimated by the swept area method by strata during the EU bottom survey (1988-2003).

		Biomass estimated by the swept area meted (tons)													
Strata	Depth (m)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003[1]
1 – 6	125-252						10	26							12
7	253-360			0								3			
8	253-360		1					13	3		8		19	2	18
9	253-360		6	33	25	4	25	182	22	48	54	35	35		41
10	253-360							7	1		21	81	21		
11	253-360										3	9	7		
12	261-540	47	129	119	491	65	150	55	163	66	227	96	281	183	223
13	261-540	21	21	71	22	38	89	6	22	93	109	60	138	144	166
14	261-540	127	101	165		87	80	321	92	231	161	123	347	147	468
15	261-540	35	76	62	382	98	214	100	82	120	86	122	71	19	118
16	541-720	252	273	514	1586	622	305	472	251	482	179	268	402	324	476
17	541-720	37	214	146		117	153	32	138	243	114	80	440	452	137
18	541-720	170	423	256		900	492	183	267	225	372	260	456	32	1186
19	541-720	325	344	510	1089	419	336	223	383	504	153	109	257	138	331
TOTAL		**1014**	**1587**	**1878**	**3595**	**2350**	**1855**	**1619**	**1425**	**2014**	**1488**	**1249**	**2473**	**1440**	**3175**
SOP		574	1537	1634	1775	2258	1844	1497	1411	1914	1400	1264	2370	1424	3198
Mean AFL (cm)			16.03	15.04	15.31	16.45	15.04	15.24	15.81	15.13	16.04	16.3	16.0	15.4	12.1
Mean Age					8.1	7.4	6.5	7.6	8.0	7.8	8.0	8.1	8.0	8.2	5.5

[1] transformed biomass using the Robson method.

Table 2.- Mean catch per trawl by strata and whole bank (1991-2003).

[1] transformed using the Robson method.

			Average weight per trawl (Kg.)												
Strata	Area	Depth (m)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003[1]
1 – 6	467	125-252					0.16	0.68							0.44
7	108	253-360		0.01								0.05			0.01
8	82	253-360	0.02					0.26	0.06		0.14			0.04	0.30
9	34	253-360	0.26	1.46	0.94	0.2	1.02	6.52	0.87	2.03	2.15	1.54	0.39		1.50
10	128	253-360						0.09	0.02		0.28	1.13	1.45		
11	107	253-360									0.06	0.15	0.29		
12	90	261-540	2.47	2.31	8.79	1.08	3.12	1.08	3.04	1.28	4.19	1.91	0.11	3.58	3.84
13	31	261-540	1.16	3.36	1.13	2.01	4.85	0.33	1.18	4.83	5.05	3.09	5.57	7.77	8.54
14	72	261-540	2.08	3.61		1.87	1.69	6.4	1.92	5.07	3.52	2.66	7.25	3.13	8.57
15	85	261-540	1.59	1.29	6.78	1.84	4.09	2	1.58	2.32	1.61	2.24	1.40	0.38	2.18
16	82	541-720	5.33	9.48	29.26	11.72	6.21	9.93	5.1	9.39	3.59	5.26	8.44	6.64	10.85
17	23	541-720	13.9	6.67		6.29	8.85	1.9	8.18	13	5.81	4.85	26.60	27.9	8.30
18	22	541-720	25.1	16.52		40.03	28.38	1	16.95	13.37	20.85	16.75	28.50	1.97	80.33
19	54	541-720	10.8	15.46	29.13	12.71	10.52	6.84	12.21	15.09	4.49	3.43	8.04	4.45	10.35
Weighted averaged per trawl (Kg)			1.94	2.20	3.94	2.47	2.24	1.94	1.75	2.38	1.71	1.53	3.08	1.80	3.98
Nº of valid tows			117	117	101	116	121	117	117	119	117	120	120	120	114

Table 3.- Roughhead grenadier length distribution and mean AFL (‘000) for each year of the 1991-2003 period.

AFL (cm)/Year	91	92	93	94	95	96	97	98	99	00	01	02	03
2													148
3	7	29	0	0	0	7	7	113	21	7	147	90	527
4	14	104	104	0	37	59	35	33	18	33	27	36	167
5	24	321	379	47	45	215	16	95	27	71	229	202	1677
6	33	82	120	31	46	63	52	65	24	49	80	83	1199
7	77	120	515	65	60	31	111	57	17	38	81	111	592
8	25	57	226	169	72	56	98	66	23	38	149	109	684
9	41	37	112	98	139	46	76	208	35	65	74	62	431
10	40	36	182	231	342	113	94	177	93	27	57	22	702
11	97	49	156	196	295	116	31	121	205	86	95	46	434
12	215	53	200	117	527	160	173	155	102	105	133	51	455
13	253	98	177	100	271	255	195	217	141	145	161	83	454
14	275	259	307	255	131	308	395	496	190	171	388	170	539
15	208	298	560	236	185	212	317	577	324	127	402	196	845
16	221	256	890	213	275	308	208	489	447	295	442	288	925
17	271	187	715	426	332	244	90	345	394	296	392	249	718
18	315	197	613	469	412	244	127	197	330	218	524	215	827
19	266	155	505	440	433	308	163	215	201	224	444	269	513
20	226	210	364	248	280	270	148	159	142	146	356	204	325
21	86	112	282	166	151	114	107	144	128	103	209	178	262
22	81	81	193	101	73	101	113	157	47	88	93	101	165
23	45	74	244	71	16	31	83	50	55	37	80	70	179
24	31	35	95	73	26	46	82	88	32	39	86	29	31
25	0	35	50	72	26	21	45	68	39	37	104	35	16
26	22	62	78	43	19	29	52	38	0	37	46	24	12
27	16	29	31	24	28	21	53	23	9	8	49	36	22
28	25	29	58	8	13	8	22	7	14	13	64	8	0
29	16	21	58	46	0	0	15	23	8	7	16	30	0
30	16	44	17	19	9	8	0	17	25	7	45	8	0
31	0	10	0	31	6	7	7	0	0	7	15	0	0
32	0	14	0	11	7	14	8	0	0	0	8	0	0
33	0	0	0	0	0	0	0	0	0	0	0	7	0
34	0	0	0	0	0	0	0	7	0	8	0	8	0
35	0	0	0	0	0	0	0	0	0	7	0	0	13
Total	**2946**	**3094**	**7231**	**4006**	**4256**	**3415**	**2923**	**4407**	**3091**	**2539**	**4996**	**3020**	**12862**
Mean AFL (cm)	**16,53**	**15,54**	**15,81**	**16,95**	**15,54**	**15,74**	**16,31**	**15,63**	**16,54**	**16,64**	**16.50**	**15.85**	**12.07**

Table 4.- Mean Age-Length key (1994-2003).

Males																					
Length / Age	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Total**
2	1																				1
3	13	1																			14
4	2	10																			12
5		19																			19
6		20	9																		29
7		1	21																		22
8		3	23	9																	35
9		1	24	25	2																52
10			7	33	13																53
11			2	24	33	6															65
12			1	5	38	25	7	1													77
13				2	20	41	21														84
14					15	42	28	12	1												98
15					2	27	35	25	6												95
16					3	17	43	36	26	7	1										133
17						9	23	33	30	27	2										124
18						1	10	30	33	31	19	4	3		1						132
19							6	13	28	32	26	14	5	2	1		1				128
20								3	17	21	19	26	10	3							99
21								1	9	6	13	20	7	3	1	4	1				65
22										2	2	5	3	3					1	1	17
23													1	2				1			4
24														1						1	2
25																					
26											1										1
Total	**16**	**55**	**87**	**98**	**126**	**168**	**173**	**154**	**150**	**126**	**83**	**69**	**29**	**14**	**3**	**4**	**2**	**1**	**1**	**2**	**1361**

Table 4.- (continued).

Females	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
2																						
3	9																					9
4		13																				13
5		29	1																			30
6		22	11																			33
7		11	35																			46
8		2	36	8																		46
9			23	25	4																	52
10			10	40	16																	66
11			1	30	31	4																66
12				11	33	26	1	1														72
13				1	37	37	9	1	1													86
14					16	39	27	8														90
15					4	32	33	23	4	1												97
16					2	16	37	30	12	3												100
17						8	32	34	20	3												97
18							14	27	30	19	1											91
19							3	22	41	26	10	3										105
20								8	29	34	22	7										100
21								4	12	31	20	7	5	1								80
22									4	18	32	20	12	3								89
23									2	2	20	16	12	2	4							58
24									1	5	10	18	16	7	2							59
25										1	6	9	14	14	4	1						49
26										1	1	12	9	3	7	3						36
27										1	1	1	8	8	8	1	2					30
28													3	10	5	2	1					21
29												1	1	1	4	5		1				13
30											1		1	4	6		4					16
31															2	1		2		1		6
32												1		1	1	1	1					5
34																1		1			1	3
35																			1			1
Total	**9**	**77**	**117**	**115**	**143**	**162**	**156**	**158**	**156**	**145**	**124**	**95**	**81**	**54**	**43**	**15**	**8**	**4**	**1**	**1**	**1**	**1665**

Table 5.- Roughhead grenadier age composition ('000) in Flemish Cap 1993-2003.

	1993			1994			1995			1996			1997			1998		
Age	M	F	Tot	M	F	Tot	M	F	Tot	M	F	Tot	M	F	Tot	M	F	Tot
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	13	39
2	0	8	8	0	9	9	20	38	58	46	24	70	14	21	35	63	130	193
3	112	248	359	17	36	53	92	104	196	35	79	114	83	149	232	119	135	254
4	173	162	335	143	121	264	190	247	437	116	84	200	53	106	159	125	121	246
5	120	151	271	108	139	247	360	443	803	149	172	321	73	89	162	90	49	139
6	445	207	652	187	101	288	324	259	583	365	194	559	214	230	444	141	201	342
7	621	570	1190	224	104	328	385	180	565	191	157	348	284	309	593	411	322	733
8	437	413	850	169	134	303	343	240	583	232	127	359	59	110	169	549	410	959
9	309	353	663	124	160	284	162	192	354	167	85	252	71	111	182	125	155	280
10	278	257	535	42	133	175	41	111	152	199	127	326	78	63	141	156	120	276
11	248	327	575	0	113	113	0	39	39	226	97	323	74	130	204	101	73	174
12	128	205	334	28	50	78	0	33	33	68	52	120	103	127	230	99	149	248
13	69	149	218	0	47	47	0	27	27	15	34	49	44	110	154	60	147	207
14	6	62	67	0	0	0	0	7	7	0	44	44	15	55	70	34	68	102
15	0	85	85	0	22	22	0	22	22	0	5	5	0	56	56	0	61	61
16	0	31	31	0	0	0	0	0	0	0	14	14	0	18	18	0	31	31
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	15
18	0	0	0	0	0	0	0	0	0	0	0	0	0	18	18	0	0	0
Total	**2946**	**3228**	**6174**	**1042**	**1169**	**2211**	**1917**	**1942**	**3859**	**1809**	**1295**	**3104**	**1165**	**1702**	**2867**	**2099**	**2200**	**4299**
Mean Age	**7,79**	**8,39**	**8,10**	**6,79**	**7,93**	**7,39**	**6,33**	**6,57**	**6,45**	**7,62**	**7,60**	**7,61**	**7,60**	**8,24**	**7,98**	**7,53**	**8,12**	**7,83**
S.D.	**2,37**	**3,10**	**2,79**	**1,93**	**2,88**	**2,54**	**1,76**	**2,56**	**2,20**	**2,53**	**3,09**	**2,78**	**2,84**	**3,60**	**3,33**	**2,74**	**3,58**	**3,21**

	1999			2000			2001			2002			2003			All		
Age	M	F	Tot	M	F	Tot	M	F	Tot	M	F	Tot	M	F	Tot	M	F	Tot
1	10	0	10	0	0	0	62	13	75	37	6	43	124	44	168	259	76	335
2	0	36	36	30	62	92	170	161	331	133	118	251	1306	1422	2728	1782	2029	3811
3	20	34	54	61	46	107	94	185	279	109	145	254	652	780	1432	1394	1941	3334
4	128	81	209	43	29	72	54	80	134	15	43	58	412	496	908	1452	1570	3022
5	108	83	191	106	124	230	111	128	239	60	44	104	381	455	836	1665	1877	3543
6	92	153	245	145	142	287	214	245	459	72	111	183	519	347	866	2718	2190	4908
7	303	143	446	111	114	225	270	266	536	138	148	286	666	498	1164	3604	2811	6415
8	383	278	661	149	125	274	287	231	518	167	128	295	862	392	1255	3638	2588	6226
9	274	210	484	260	159	419	325	264	589	139	124	263	435	321	755	2391	2134	4525
10	131	113	244	169	187	356	339	480	819	130	184	314	360	316	675	1923	2091	4014
11	87	55	142	19	67	86	83	214	297	149	109	258	326	356	683	1314	1580	2894
12	48	59	107	43	78	121	76	94	170	125	189	314	166	179	345	884	1215	2099
13	25	49	74	15	51	66	8	97	105	0	58	58	75	54	129	311	824	1134
14	35	47	82	12	40	52	8	132	140	37	69	106	27	18	44	174	541	715
15	5	39	44	8	22	30	7	61	68	10	16	26	0	26	26	30	415	445
16	0	4	4	31	29	60	8	98	106	34	57	91	25	0	25	98	282	380
17	0	0	0	0	0	0	0	0	0	0	0	0	35	22	57	35	37	72
18	0	0	0	0	0	0	0	0	0	0	0	0	14	13	27	14	31	45
Total	**1649**	**1384**	**3033**	**1202**	**1275**	**2477**	**2116**	**2749**	**4865**	**1355**	**1549**	**2904**	**6385**	**5739**	**12124**	**23685**	**24232**	**47917**
Mean Age	**7,92**	**8,19**	**8,04**	**7,92**	**8,34**	**8,14**	**7,33**	**8,47**	**7,97**	**7,84**	**8,45**	**8,17**	**6,05**	**5,62**	**5,84**	**7,09**	**7,49**	**7,29**
S.D.	**2,35**	**2,96**	**2,65**	**2,87**	**3,30**	**3,11**	**2,96**	**3,63**	**3,40**	**3,69**	**3,83**	**3,78**	**3,40**	**3,45**	**3,43**	**2,96**	**3,53**	**3,26**

Table 6. Logarithmic growth regression curves, fitted to mean length at age data, for male and female roughhead grenadier from EU Survey (1993-2003).

	MALES		FEMALES	
Year	Regression	r^2	Regression	r^2
1993	AFL (cm) = 8.8156 Ln (A) - 1.8999	0.986	AFL (cm) = 12.999 * Ln (A) - 8.6786	0.979
1994	AFL (cm) = 13.034 Ln (A) - 8.1095	0.924	AFL (cm) = 12.394 * Ln (A) - 5.4082	0.941
1995	AFL (cm) = 8.8152 Ln (A) - 0.2014	0.951	AFL (cm) = 12.268 * Ln (A) - 5.1506	0.950
1996	AFL (cm) = 8.9440 Ln (A) - 1.6428	0.991	AFL (cm) = 12.241 * Ln (A) - 6.1702	0.955
1997	AFL (cm) = 8.7078 Ln (A) - 1.6519	0.992	AFL (cm) = 12.118 * Ln (A) - 6.4209	0.955
1998	AFL (cm) = 7.1799 Ln (A) + 1.3319	0.968	AFL (cm) = 9.5935 * Ln (A) - 1.4863	0.918
1999	AFL (cm) = 7.4754 Ln (A) + 1.1001	0.962	AFL (cm) = 9.6124 * Ln (A) - 1.1061	0.924
2000	AFL (cm) = 7.835 * Ln (A) – 0.0057	0.990	AFL (cm) = 12.923 * Ln (A) – 7.6958	0.933
2001	AFL (cm) = 7.266*Ln (A) + 1.4463	0.975	AFL (cm) = 10.291 * Ln (A) – 1.9577	0.942
2002	AFL (cm) = 7.079 *Ln (A) + 1.2645	0.973	AFL (cm) = 10.551 * Ln (A) – 2.5121	0.913
2003	AFL (cm) = 7.208 *Ln (A) + 1.3007	0.971	AFL (cm) = 9.443 * Ln (A) – 1.1958	0.904

Table 6b. Parameters of the Von Bertalanffy growth curves, fitted to individual length at age using non-linear regression, by sex for the EU Survey 1993-2003.

	MALES			FEMALES		
Year	t_o	L_∞	**K**	t_o	L_∞	**K**
1993	1.074	21.9	0.197	0.634	46.4	0.060
1994	1.768	22.8	0.254	-0.054	57.6	0.048
1995	-1.576	37.1	0.073	-0.681	51.9	0.053
1996	0.490	23.5	0.172	0.346	77.0	0.032
1997	1.425	22.9	0.176	0.533	51.2	0.050
1998	0.270	27.5	0.109	0.460	46.3	0.056
1999	-0.132	27.9	0.104	0.405	57.8	0.044
2000	0.199	25.8	0.128	-0.079	68.7	0.034
2001	0.950	23.9	0.159	0.350	52.3	0.051
2002	0.072	25.0	0.128	-0.089	63.8	0.054
2003	0.050	26.0	0.120	-0.357	42.4	0.061

Table 7.- Length weight relationship for roughhead grenadier males and females from EU Survey (1993-2003).

	MALES		FEMALES	
Year	Regression	r^2	Regression	r^2
1993	$W(g) = 0.0793 * AFL(cm)^{3.0883}$	0.9734	$W(g) = 0.1016 * AFL(cm)^{2.9934}$	0.9895
1994	$W(g) = 0.1489 * AFL(cm)^{2.8437}$	0.9694	$W(g) = 0.1015 * AFL(cm)^{2.9935}$	0.9895
1995	$W(g) = 0.1131 * AFL(cm)^{2.9409}$	0.9818	$W(g) = 0.1139 * AFL(cm)^{2.9344}$	0.9859
1996	$W(g) = 0.1244 * AFL(cm)^{2.8889}$	0.9802	$W(g) = 0.1367 * AFL(cm)^{2.8536}$	0.9851
1997	$W(g) = 0.1209 * AFL(cm)^{2.8840}$	0.9812	$W(g) = 0.1202 * AFL(cm)^{2.8898}$	0.9923
1998	$W(g) = 0.1338 * AFL(cm)^{2.8621}$	0.9669	$W(g) = 0.1199 * AFL(cm)^{2.9015}$	0.9866
1999	$W(g) = 0.1290 * AFL(cm)^{2.8670}$	0.9718	$W(g) = 0.1174 * AFL(cm)^{2.8950}$	0.9866
2000	$W(g) = 0.1423 * AFL(cm)^{2.8148}$	0.9776	$W(g) = 0.1708 * AFL(cm)^{2.7537}$	0.9744
2001	$W(g) = 0.2747 * AFL(cm)^{2.5821}$	0.9637	$W(g) = 0.1922 * AFL(cm)^{2.716}$	0.9859
2002	$W(g) = 0{,}143 * AFL(cm)^{2,8218}$	0.9878	$W(g) = 0{,}119 * AFL(cm)^{2,884}$	0.9921
2003	$W(g) = 0{,}103 * AFL(cm)^{2,9376}$	0.9797	$W(g) = 0{,}101 * AFL(cm)^{2,9391}$	0.9911

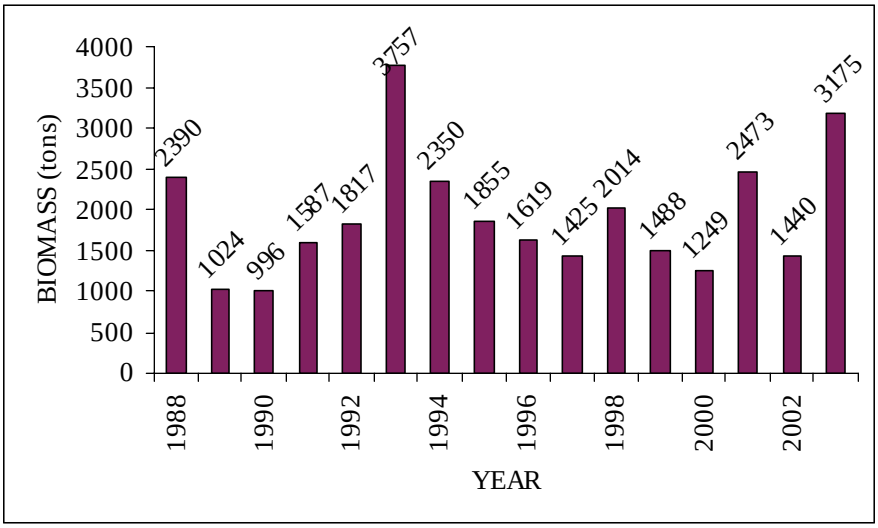

Fig. 1. Total biomass estimated by the swept area method for the area studied during the EU bottom trawl survey (1988-2003). 2003: biomass transformed using the Robson method.

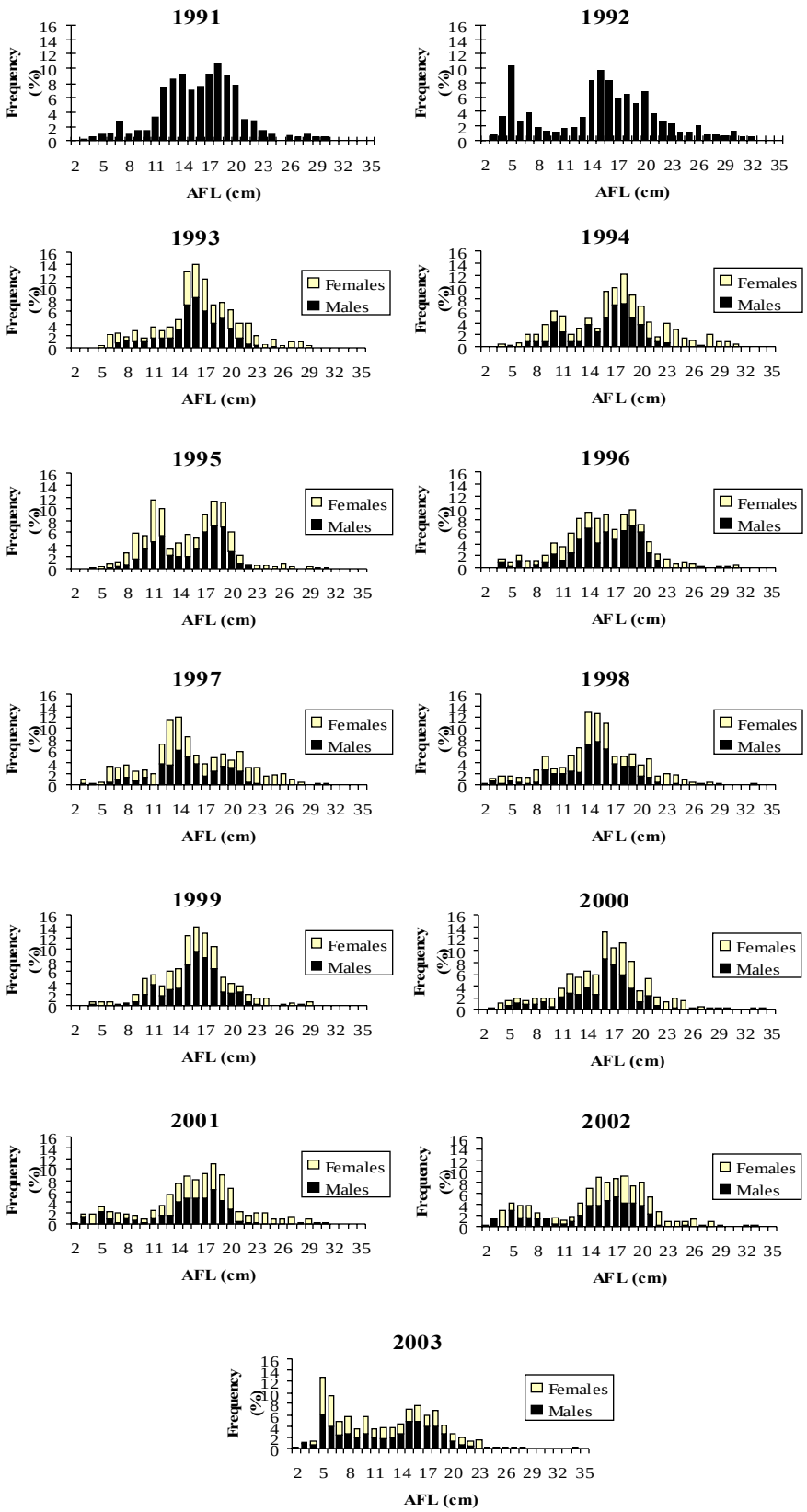

Fig. 2. Annual length distribution by sex (except 1991-1992) in Flemish Cap 1991-2003.

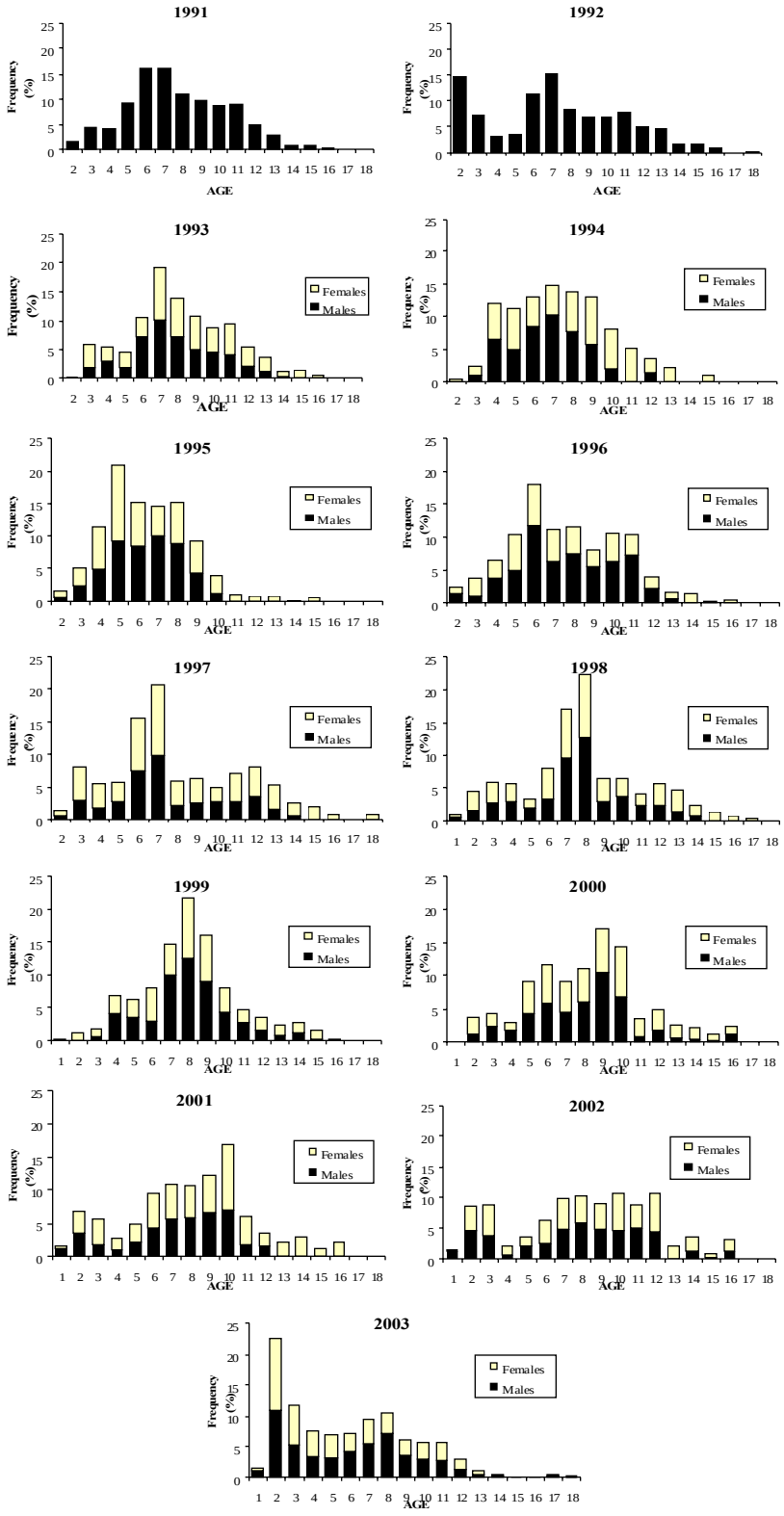

Fig. 3. Annual age composition by sex (except 1991-1992), in Flemish Cap 1991-2003.

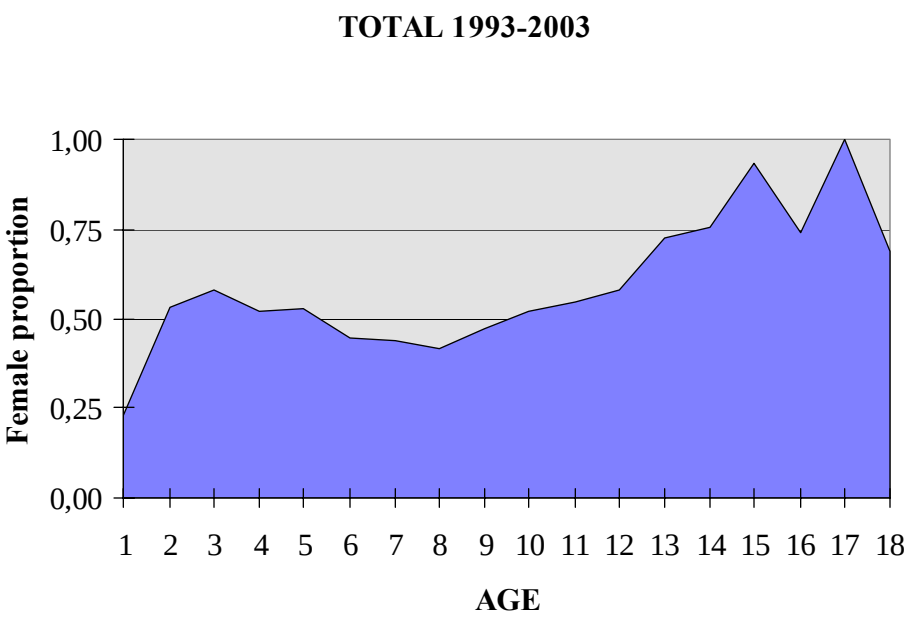

Fig. 4. Female ratio by age in Flemish Cap 1993-2003.

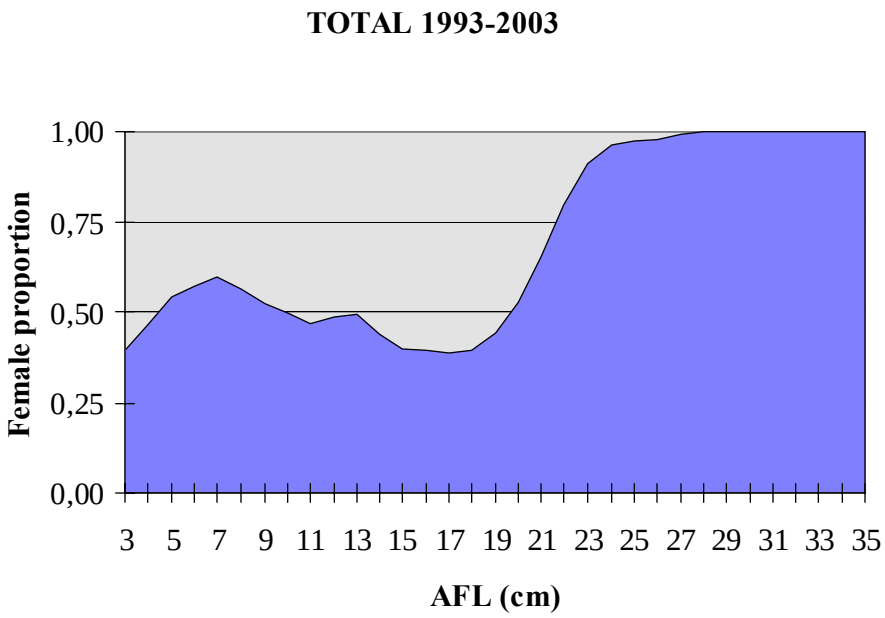

Fig. 5. Female ratio by length in Flemish Cap 1993-2003.

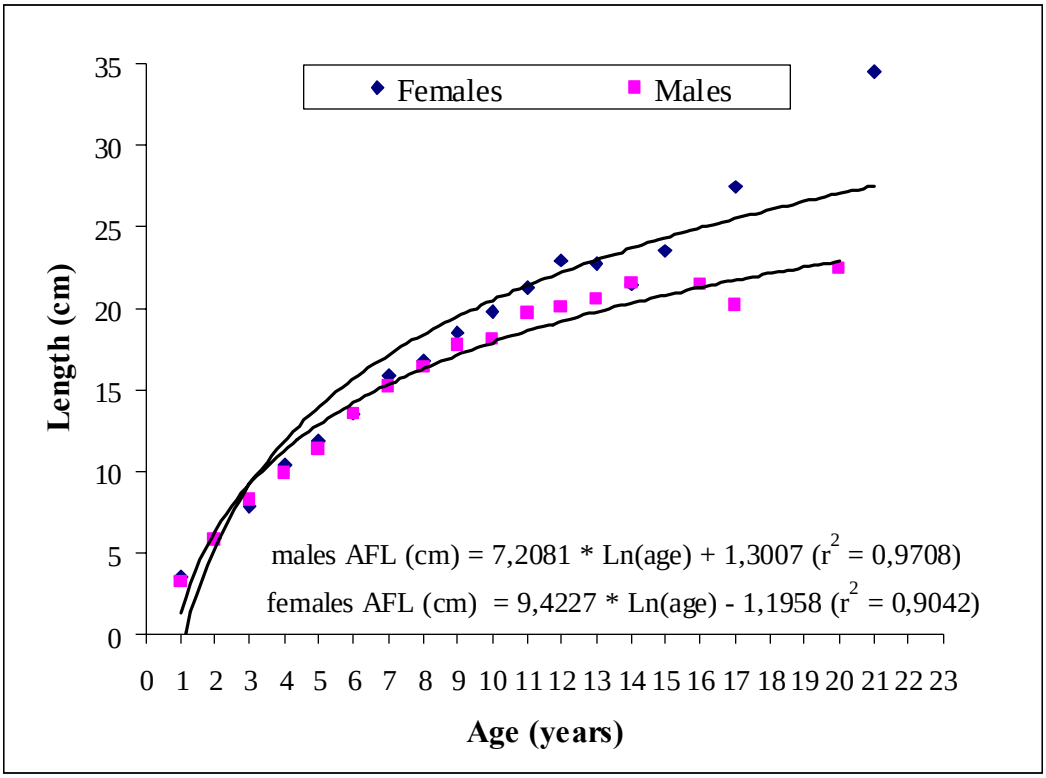

Fig. 6. Logarithmic growth curve by sexes in Flemish Cap 2003.

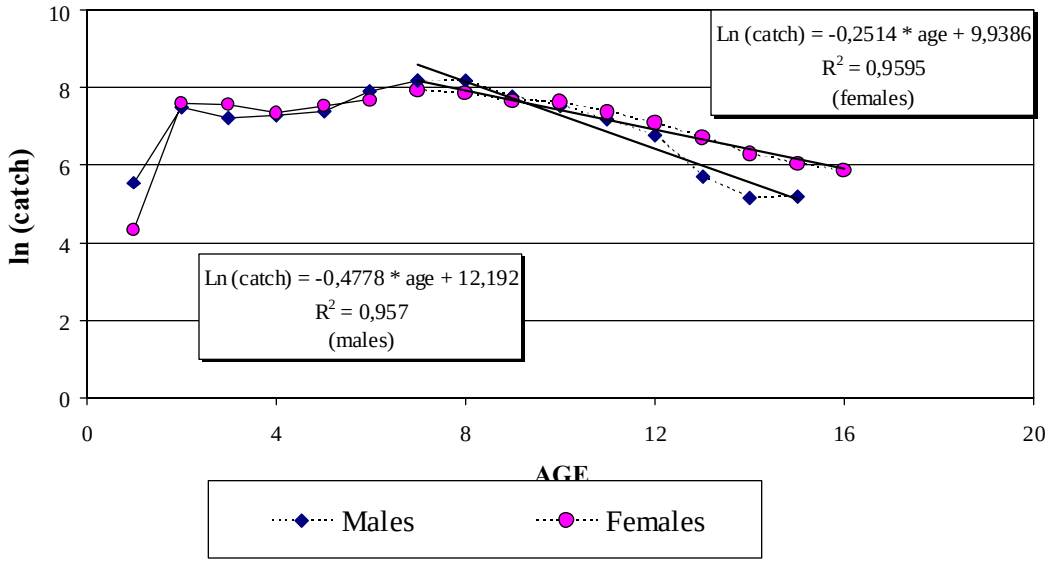

Fig. 7. Catch curves by sex for roughhead grenadier in Flemish Cap 1994-2003.

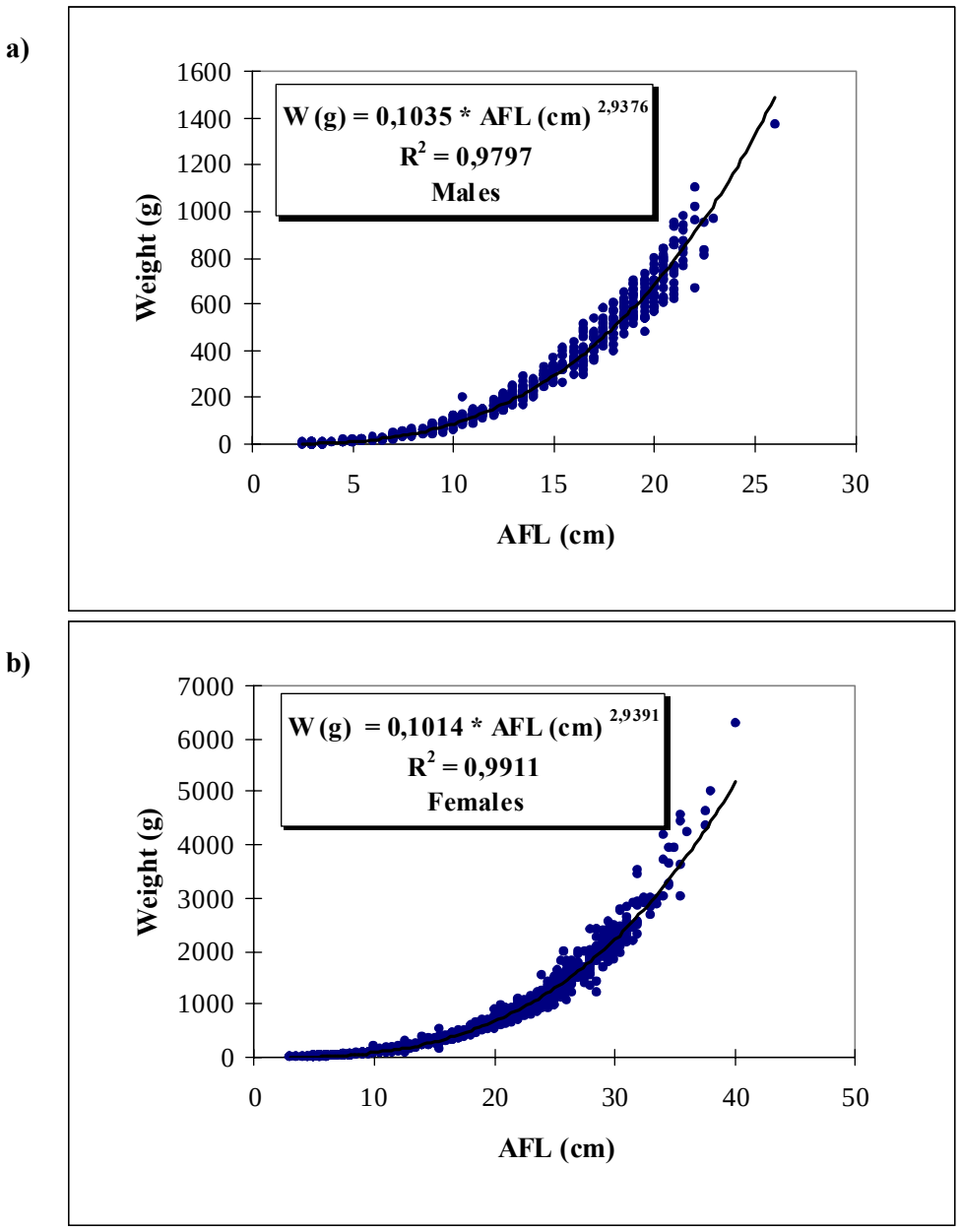

Fig. 8. Length weight relationship for (a) males and (b) females of roughhead grenadier in 2003.