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A Review on Roughhead Grenadier (*Macrourus berglax*) Biology and Population Structure on Flemish Cap (NAFO Division 3M) 1991-2005 Based Upon EU Flemish Cap Bottom Survey Data

by

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Abstract

The European Union has conducted since 1988 an annual bottom trawl survey in Flemish Cap (NAFO Division 3M) in the 200-720 m depth range. The information on roughhead grenadier population structure recorded during the last 14 EU surveys (1991-2005) in Flemish Cap is presented. Depth distribution of captures, length/age distribution of captures, growth rates, sex-ratios, catch curves, and abundance/biomass estimated by the swept area method are presented.

In general, the biomass index increased from low levels to a peak of about 3 000 tons in 1993, then decreased in 1994 and remained around 1 500 and 2 000 tons till 2002. It increased again in 2003 to reach the peak of 3 575 tons in 2004. The biomass index in 2005 was 2 387 tons.

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 classes.

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; Murua and de Cardenas, 2005). It has, however, been found in depths up to 2 700 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 catch decreased to about 3 182 tons in 2004 (González-Costas and Murua, 2005).

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. In 2003 and 2004 the survey was extended to depths down to 1 400 meters. 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. From 2003 onward, the survey was carried out with a new R/V *Vizconde de Eza*, which replaced the former C/V *Cornide de Saavedra*. In order to make comparable both series, comparative fishing trials were carried out to calibrate both series in 2003 and 2004 (González-Troncoso and Casas, 2005).

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 the abundance indices and biomass estimates by the Flemish Cap survey as well as some biological and population structure information of roughhead grenadier in Flemish Cap during the period 1991-2005. The results are presented taking into account that the survey only covers the shallowest distribution area of roughhead grenadier. The information is presented as an update of continued analyses of the survey results (Murua *et al.*, 2005.).

Material and Methods

Data on roughhead grenadier for the 1991-2005 period were collected on the annual random-stratified bottom trawl surveys carried out by the European Union on the area (Casas *et al.*, 2006). In order to maintain the data series, comparative fishing trials were carried out to develop conversion factors for the species sampled in 2003 and 2004. In total, 130 paired hauls with *Cornide de Saavedra* and *Vizconde de Eza* were done (in which 23 roughhead grenadier appeared) and the conversion factor to transform the Cornide values to *Vizconde de Eza* equivalents were estimated (Gónzalez-Troncoso and Casas, 2005). As the depth coverage increased from 2003 onwards, the data presented here refers to survey results of depth <720 meters, i.e. the common depth coverage in all the time series. Data on length distribution by sex is only available from 1993 onwards and age structure data is only available for the 1994-2005 period. Otolith sampling began in 1994, and since then a total of 5 820 otoliths have been read. Annual length-age keys have been applied for each year.

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 1 211 tons and then increased reaching the highest level (3 597 tons) of the time series in 2004. In 2005 the biomass was estimated in 2 387 tons, which is at the same level of 2003 and higher than the period 1994-2002. 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; Murua and de Cárdenas, 2005).

Table 3 shows length distributions of roughhead grenadier for the 1991-2005 period. Captures are dominated by the 14-20 cm length classes, 50% of the total catch, in most of the years. However, during the most recent three surveys the captures are dominated by the <14 cm length, between 60% in 2003 and 45% in 2005. Moreover, the proportion of 2-8 length range has increased considerably to around 39 and 32% during 2003 and 2004 survey respectively; which in turn may be interpreted as a sign of a good 2001 year class recruiting to the population (Table 3).The average AFL for both sexes for all the period is 14.79 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 (Murua and de Cárdenas, 2005).

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 36 cm long. Average AFL for females is also greater than for males. Female's mean AFL for the 1993-2005 period in Flemish Cap was 15.6 cm, while mean AFL for males was 14.6 cm. This sexual difference is consistent with data found in the literature (Murua and González-Costas, 2005). 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 3LN, where females are larger than males (Junquera *et al*., 2001).

The AFL-age key for 2005 is given by sex in Table 4. Table 5 shows age composition by sexes for roughhead grenadier in Flemish Cap in 1993-2005. The oldest male found in the period studied was 19 years old and the oldest female 24 years old. Mean age for females in Flemish Cap in the 1993-2005 period was 7.0 years, while mean age for males was 6.9 years.

Interannual differences in length and age are shown in Fig. 2 and 3. The 1990-1991 cohorts were the most important cohorts in abundance during the 1995-1999. The importance of these annual classes has declined sharply during last years. In 2003 and 2004, 23% and 27% of the individuals, respectively, were composed by individuals of 2001 year-class; this 2001 year-class is by far the most abundant year-class either at age 2 or age 3 in the time series (Fig. 4). However, although the pulse of this large 2001 year-class was still observable in 2005, it was not as high as one would expect.

Female-ratio in the whole study period was 50%. This value was 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 and depth 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 5 and 6 present sex-ratio by age and by length respectively, for the whole study period. In the sex-ratio, female proportion fluctuated around 40%-50% up to 20 cm in length (the first 10-12 years) and increased to 75% at 22 cm (13 years) and 80% at 24 cm (15 years). Following this length, 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. 7), fitted to mean length at age by sex, show that males growth rate declines when reaching 9 years old, around 18 cm long, while females do not decline growing until reaching 20 years old, around 30-35 cm. 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 survey gear, using data of eleven years (1994-2005). Both sexes are fully recruited at age 8 and the mortality obtained is different for both sexes: 0.47 for females and 0.62 for males (Fig. 8).

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 9 shows the length-weight relationship by sexes in 2005 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; 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 (1991-2005); biomass series transformed to Vizconde de Eza equivalents from 1988-2002.

		Biomass estimated by the swept area meted (tons)														
Strata	Depth (m)	91	92	93	94	95	96	97	98	99	2000	2001	2002	2003	2004	2005
1 – 6	125-252					8	22							9	10	
7	253-360										3				10	
8	253-360	1					11	3		7		16	2	13	28	65
9	253-360	5	28	21	3	21	153	18	40	45	29	29		30	282	82
10	253-360						6	1		18	68	18			48	38
11	253-360									3	8	6			3	2
12	261-540	108	100	413	55	126	46	137	55	191	81	236	154	165	292	207
13	261-540	18	60	18	32	75	5	18	78	92	50	116	121	123	299	94
14	261-540	85	139		73	67	270	77	194	135	103	292	124	346	877	379
15	261-540	64	52	321	82	180	84	69	101	72	103	60	16	87	259	16
16	541-720	229	432	1333	523	256	397	211	405	150	225	338	272	352	594	426
17	541-720	180	123		98	129	27	116	204	96	67	370	380	101	244	124
18	541-720	356	215		756	414	154	224	189	313	219	383	27	877	423	588
19	541-720	289	429	915	352	282	187	322	424	129	92	216	116	245	228	366
TOTAL		**1335**	**1577**	**3021**	**1975**	**1558**	**1362**	**1197**	**1691**	**1250**	**1047**	**2079**	**1211**	**2348**	**3597**	**2387**
Error biomass		250	270	487	169	223	277	169	243	338	196	284	176	611	362	281
Mean AFL (cm)		16.35	15.82	15.84	16.62	15.25	15.76	16.01	15.61	16.34	16.48	16.55	16.10	12.00	13.32	14.89

Table 2. Mean catch per trawl by strata and whole bank (1991-2005); series transformed to Vizconde de Eza equivalents.

			Average weight per trawl (Kg.)														
Strata	Area	Depth (m)	91	92	93	94	95	96	97	98	99	2000	2001	2002	2003	2004	2005
1 – 6	467	125-252					0.13	0.58							0.34	0.19	
7	108	253-360													0.04		
8	82	253-360		0.20		0.02					0.22	0.05		0.14		0.32	0.03
9	34	253-360	1.97	0.18		0.21	1.16	0.88	0.14	0.88	6.39	0.77	1.69	1.90	1.23	1.23	
10	128	253-360	0.01								0.08	0.01		0.24	0.94	0.24	
11	107	253-360												0.04	0.12	0.10	
12	90	261-540	2.19	2.03	0.77	2.12	1.96	8.08	1.07	2.47	0.91	2.68	1.09	3.74	1.58	4.63	3.01
13	31	261-540	1.11	3.37	0.93	0.93	3.15	0.97	1.68	3.94	0.27	0.97	4.12	4.83	2.66	6.11	6.38
14	72	261-540	4.36	3.15	2.33	1.85	3.02		1.59	1.47	5.88	1.69	4.23	2.95	2.25	6.36	2.69
15	85	261-540	1.81	0.10	0.58	1.26	1.03	6.33	1.62	3.54	1.66	1.36	1.99	1.42	2.02	1.18	0.31
16	82	541-720	7.22	2.91	4.38	4.75	8.94	27.60	10.82	5.31	8.21	4.37	8.39	3.11	4.66	6.99	5.64
17	23	541-720	8.12	2.71	1.89	10.93	7.46		5.98	7.81	1.63	7.05	12.41	5.82	4.09	22.47	23.08
18	22	541-720	19.44	7.98	8.93	22.22	13.45		47.28	25.84	9.61	14.03	11.82	19.54	13.66	23.95	1.68
19	54	541-720	23.55	7.19	8.66	9.17	13.59	29.02	11.16	8.95	5.94	10.21	13.43	4.08	2.90	6.85	3.68
Weighted averaged per trawl (Kg)			**1.66**	**1.96**	**3.76**	**2.46**	**1.94**	**1.69**	**1.49**	**2.10**	**1.56**	**1.31**	**2.58**	**1.50**	**2.92**	**4.47**	**2.97**
S. D.			0.31	0.34	0.61	0.21	0.28	0.34	0.21	0.30	0.42	0.24	0.35	0.22	0.76	0.45	0.35
Nº of valid tows			117	117	101	116	121	117	117	119	117	120	120	120	114	124	117

Table 3. Roughhead grenadier length distribution and mean AFL (,000) for each year of the 1991-2005 period (transformed series to Vizconde de Eza equivalents).

AFL (cm)	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
1		7	3												
2		13											99	21	10
3	4	16				3	3	48	9	3	65	40	369	294	120
4	6	57	42		16	26	15	14	8	15	12	16	119	59	51
5	16	232	200	28	24	127	9	53	15	42	133	118	1220	566	139
6	26	73	77	22	31	45	36	44	16	35	56	59	881	481	95
7	69	121	380	53	46	25	87	45	14	31	65	90	437	705	134
8	25	64	184	154	61	51	86	57	20	34	133	99	506	1576	167
9	43	45	98	96	126	45	71	194	33	63	71	60	319	495	441
10	45	46	167	237	325	116	92	173	92	28	57	23	520	493	542
11	111	63	146	207	289	123	32	121	209	89	98	48	321	420	282
12	248	69	190	125	521	171	176	157	105	110	139	54	337	631	284
13	291	128	168	107	267	271	198	220	144	152	168	87	332	584	288
14	312	334	288	269	128	323	396	495	193	177	399	177	393	635	329
15	231	374	513	243	176	217	310	563	321	129	404	199	611	592	351
16	238	312	790	212	253	306	197	462	428	290	430	283	666	697	315
17	280	219	610	408	294	233	82	314	363	279	367	235	511	746	309
18	311	221	499	429	348	222	111	171	290	196	468	194	583	696	518
19	223	147	349	341	310	238	120	158	150	171	336	206	359	519	443
20	190	199	251	192	201	209	109	117	106	111	269	156	225	376	277
21	72	106	195	129	108	88	79	106	95	79	158	136	180	266	187
22	68	77	133	78	53	78	83	115	35	67	70	77	111	202	123
23	38	71	168	55	12	24	61	37	41	28	60	54	121	143	76
24	26	33	66	57	19	36	61	64	24	30	65	23	20	115	83
25		33	35	56	19	16	33	50	29	28	79	27	10	85	70
26	18	59	54	33	13	23	39	28	0	28	35	18	8	72	60
27	14	28	21	19	20	16	39	17	7	6	37	28	14	31	28
28	21	28	40	6	9	6	16	5	11	10	48	6		28	8
29	14	20	40	36	0	0	11	17	6	5	12	23		10	20
30	14	41	12	14	6	6	0	13	19	5	34	6		19	18
31		9		24	4	5	5			5	12			19	0
32		13		8	5	11	6				6				
33	6											5		9	
34	7							5		6		6	8		
35										5					
36		6		8											
Total	**2966**	**3265**	**5718**	**3647**	**3684**	**3060**	**2565**	**3862**	**2784**	**2259**	**4288**	**2550**	**9277**	**11585**	**5767**
Mean AFL (cm)	**16.35**	**15.82**	**15.84**	**16.62**	**15.25**	**15.76**	**16.01**	**15.61**	**16.34**	**16.48**	**16.55**	**16.10**	**12.00**	**13.32**	**14.89**

Table 4. Age-Length key for roughhead grenadier gathered in Flemish Cap 2005.

Males

AFL(cm)/age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	18	Total
3	1	1															**2**
4	1	5															**6**
5		10															**10**
6		3	7														**10**
7		4	6														**10**
8			4	5													**9**
9			3	4	3												**10**
10			1	6	3												**10**
11				2	4	4											**10**
12					3	7											**10**
13					2	7	1										**10**
14						2	7	1									**10**
15						1	5	3	1								**10**
16							2	7	1								**10**
17								3	5	1	1						**10**
18									3	4	1		2	1			**11**
19										5	1	1	1	2			**10**
20									1	2	5	1					**9**
21										1	1	1	3	4			**10**
22											1	4	3	1			**9**
23												1	2	3			**6**
24													1	1			**2**
25															1	1	**2**
28												1		1			**2**
29												1	1				**2**
Total	**2**	**23**	**21**	**17**	**15**	**21**	**15**	**14**	**11**	**13**	**10**	**10**	**13**	**13**	**1**	**1**	**200**

Table 4. (continued)

Females

AFL(cm)/age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
4	4																						**4**
5	6																						**6**
6	2	8																					**10**
7	1	9																					**10**
8		7	3																				**10**
9		1	8	1																			**10**
10			5	5																			**10**
11			6	2	2																		**10**
12				6	4																		**10**
13				3	4	3																	**10**
14				2	1	6	1																**10**
15					5	3	2																**10**
16						3	5		1														**9**
17							8	2															**10**
18							4	3	2	1													**10**
19							1	3	4	2													**10**
20								1	5	3		1											**10**
21									4	2	4												**10**
22									3	4	2		1										**10**
23									1	3	1	4	1										**10**
24											4	4	2										**10**
25										2	1	4	3										**10**
26												3	4	1		2							**10**
27												3	5	2									**10**
28													4	2		3	1						**10**
29												2		2	2	1	2		1				**10**
30														3	4	1			1	1			**10**
31														1	2	3	2	2					**10**
32														1	1	1	3	3				1	**10**
33																1	3	3	2			1	**10**
34																2	2	3	2		1		**10**
35															1	1	2	1	2			1	**8**
36																1		2					**3**
37																			1	1	1		**3**
38																					1		**1**
39																					1		**1**
40																						1	**1**
45																						1	**1**
Total	**13**	**25**	**22**	**19**	**16**	**15**	**21**	**9**	**20**	**17**	**12**	**21**	**20**	**12**	**10**	**16**	**15**	**14**	**9**	**2**	**4**	**5**	**317**

Table 5. Roughhead grenadier age composition (,000) in Flemish Cap 1994-2005.

	1994			1995			1996			1997			1998			1999			2000		
Age	M	F	Tot	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	14	6	20	5	0	5	0	0	0
2	0	12	12	16	26	42	25	14	40	11	13	24	36	82	118	0	25	25	18	30	48
3	14	32	46	85	93	177	29	66	95	56	121	177	108	118	225	18	29	47	59	49	108
4	145	122	267	181	235	416	117	86	204	51	102	153	121	116	237	128	82	209	36	14	50
5	114	147	261	353	433	787	158	183	341	74	80	155	90	49	139	111	86	197	151	132	283
6	189	103	292	306	245	552	381	202	583	241	204	445	142	202	344	97	150	247	135	142	277
7	213	96	309	332	156	488	192	155	346	252	355	607	406	314	721	303	142	445	97	121	218
8	148	111	259	267	177	444	219	116	335	63	98	161	523	383	906	358	258	616	108	123	231
9	98	124	222	117	139	256	144	69	213	73	85	158	115	135	250	248	174	422	226	114	339
10	32	103	135	29	80	109	163	99	262	56	42	98	131	95	226	110	87	197	183	155	338
11	0	88	88	6	28	35	179	75	254	56	95	151	81	54	135	69	41	109	18	55	72
12	32	39	71	0	23	23	53	40	93	72	93	164	73	109	182	36	44	79	33	62	95
13	0	36	36	0	20	20	12	26	37	39	85	124	44	108	152	19	36	56	17	40	57
14	0	15	15	0	5	5	0	33	33	5	37	42	25	51	76	26	35	61	22	33	55
15	8	17	25	0	15	15	0	4	4	0	42	42	0	48	48	4	29	33	6	16	22
16	0	8	8	0	0	0	0	11	11	0	8	8	0	22	22	0	3	3	12	5	17
17	0	0	0	0	0	0	0	0	0	0	6	6	0	12	12	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	5	5	0	0	0	0	0	0	0	11	11
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5
20+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**993**	**1054**	**2047**	**1693**	**1674**	**3367**	**1672**	**1179**	**2852**	**1051**	**1469**	**2520**	**1908**	**1903**	**3812**	**1531**	**1221**	**2752**	**1120**	**1107**	**2227**
Mean Age	**6.8**	**7.8**	**6.9**	**6.2**	**6.3**	**6.1**	**7.4**	**7.3**	**7.1**	**7.4**	**7.9**	**7.6**	**7.5**	**8.0**	**7.6**	**7.8**	**8.0**	**7.8**	**7.8**	**8.2**	**7.9**

	2001			2002			2003			2004			2005			All		
Age	M	F	Tot	M	F	Tot	M	F	Tot	M	F	Tot	M	F	Tot	M	F	Tot
1	29	6	35	17	3	19	86	31	117	69	26	95	0	0	0	219	71	290
2	99	90	188	84	71	156	953	1038	1991	181	205	386	118	52	170	1540	1658	3198
3	94	172	266	96	124	220	482	576	1058	1322	1798	3119	186	162	348	2547	3339	5886
4	42	77	119	14	43	57	305	367	672	406	604	1009	253	509	762	1800	2355	4155
5	124	159	283	62	46	108	281	336	617	379	498	877	229	399	628	2127	2549	4676
6	225	218	443	75	114	189	380	254	635	670	432	1102	303	242	545	3144	2509	5654
7	261	273	533	142	148	290	483	359	843	495	308	803	262	237	499	3437	2665	6102
8	280	217	497	165	119	283	620	281	901	606	346	951	257	337	594	3612	2565	6178
9	285	220	505	131	110	241	309	226	535	498	461	959	226	187	413	2469	2044	4513
10	294	369	663	118	148	266	255	220	475	519	374	893	248	331	579	2138	2102	4240
11	63	167	230	120	84	204	227	245	472	258	206	465	145	226	371	1224	1362	2586
12	54	77	131	99	145	243	115	120	236	200	190	390	51	116	167	817	1059	1876
13	7	74	81	30	45	75	52	36	88	22	125	147	95	132	227	338	762	1100
14	6	98	104	10	53	63	18	12	30	23	66	90	94	97	191	231	535	766
15	7	48	55	8	12	19	0	17	17	0	18	18	0	21	21	33	287	320
16	0	30	30	20	18	39	17	0	17	0	21	21	0	9	9	50	135	184
17	0	29	29	0	9	9	25	14	39	0	23	23	0	17	17	25	110	134
18	6	6	12	0	10	10	0	0	0	0	6	6	0	3	3	6	41	48
19	0	0	0	0	0	0	10	0	10	0	6	6	0	0	0	10	11	20
20+	0	6	6	0	5	5	0	8	8	0	3	3	0	4	4	0	26	26
Total	**1876**	**2335**	**4211**	**1191**	**1306**	**2497**	**4617**	**4141**	**8758**	**5648**	**5715**	**11363**	**2466**	**3080**	**5546**	**25766**	**26185**	**51951**
Mean Age	**7.4**	**8.3**	**7.8**	**7.9**	**8.4**	**8.0**	**6.0**	**5.5**	**5.5**	**6.3**	**6.0**	**6.1**	**7.3**	**7.5**	**7.2**	**6.9**	**7.0**	**6.8**

Table 6a. Logarithmic growth regression curves, fitted to mean length at age data, for male and female roughhead grenadier from EU Survey (1994-2005). * Data from 1993-2002: original Cornide de Saavedra transformed to Vizconde de Eza data. 2003-2005 Original Vizconde de Eza data.

	MALES		FEMALES	
Year	Regression	r^2	Regression	r^2
1994*	AFL (cm) = 13.023 Ln (A) – 7.804	0.934	AFL (cm) = 13.900 * Ln (A) - 7.537	0.923
1995*	AFL (cm) = 8.948 Ln (A) - 0.020	0.954	AFL (cm) = 12.322 * Ln (A) - 4.968	0.951
1996*	AFL (cm) = 8.886 Ln (A) - 1.249	0.994	AFL (cm) = 12.283 * Ln (A) - 5.977	0.954
1997*	AFL (cm) = 8.691 Ln (A) - 1.383	0.990	AFL (cm) = 12.378 * Ln (A) - 6.439	0.939
1998*	AFL (cm) = 7.125 Ln (A) + 1.709	0.965	AFL (cm) = 9.537 * Ln (A) - 1.088	0.912
1999*	AFL (cm) = 7.137 Ln (A) + 2.140	0.952	AFL (cm) = 11.021 * Ln (A) - 3.953	0.942
2000*	AFL (cm) = 7.973 * Ln (A) – 0.054	0.984	AFL (cm) = 12.840 * Ln (A) – 7.274	0.934
2001*	AFL (cm) = 7.423*Ln (A) + 1.514	0.978	AFL (cm) = 10.282 * Ln (A) – 1.623	0.978
2002*	AFL (cm) = 7.313 *Ln (A) + 1.26	0.970	AFL (cm) = 10.606 * Ln (A) – 2.393	0.913
2003	AFL (cm) = 7.208 *Ln (A) + 1.301	0.971	AFL (cm) = 9.443 * Ln (A) – 1.196	0.904
2004	AFL (cm) = 7.677 *Ln (A) + 0.746	0.964	AFL (cm) = 10.707 * Ln (A)– 2.392	0.923
2005	AFL (cm) = 8.322 *Ln (A) - 0.858	0.970	AFL (cm) = 11.888 * Ln (A)– 6.014	0.962

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 1993-2005. 1993-2004 Data from Flemish Cap survey < 720 and * 2004-2005 data down to 1500 meters.

	MALES			FEMALES		
Year	t_0	L_∞	**K**	t_0	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
2004*	0.186	30.0	0.103	-0.461	92.5	0.025
2005*	-0.143	34.4	0.078	-0.383	71.2	0.033

Table 7. Length weight relationship for roughhead grenadier males and females from EU Survey (1993-2005).

	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
2004	$W (g) = 0,109 * AFL (cm)^{2,9125}$	0.9879	$W (g) = 0,0096 * AFL (cm)^{2,9512}$	0.9924
2005	$W (g) = 0,102 * AFL (cm)^{2,9462}$	0.9806	$W (g) = 0,0975 * AFL (cm)^{2,9555}$	0.9755

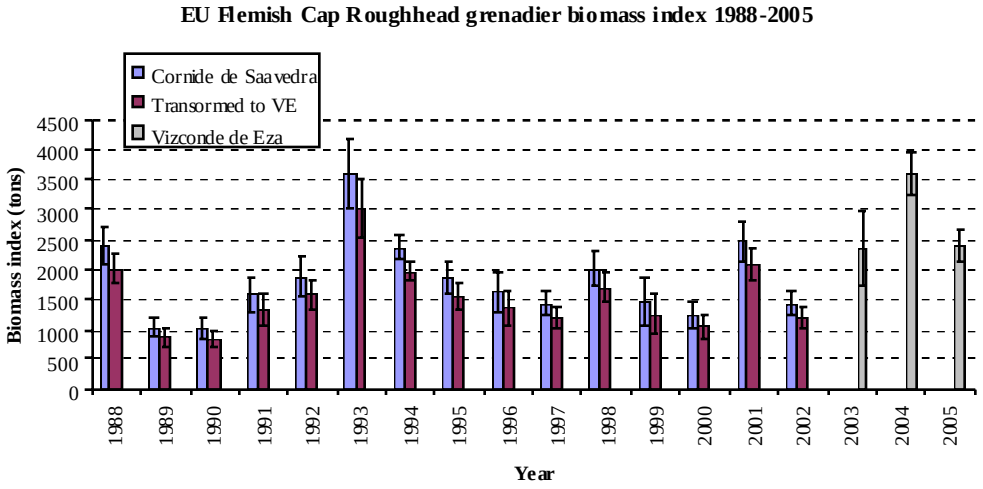

Fig. 1. Total biomass estimated by the swept area method during the EU Flemish Cap bottom trawl survey (1988-2005).

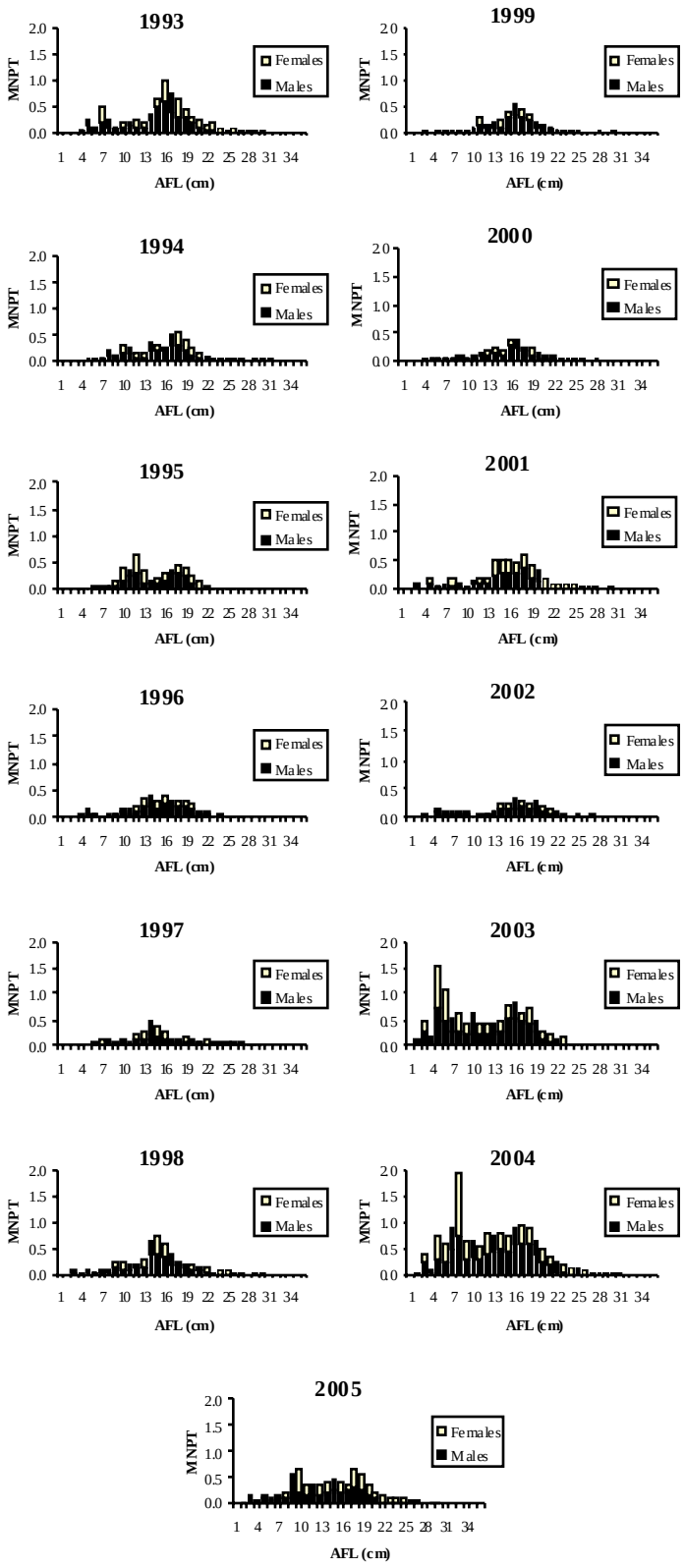

Fig. 2. Annual length distribution by sex in Flemish Cap 1993-2005.

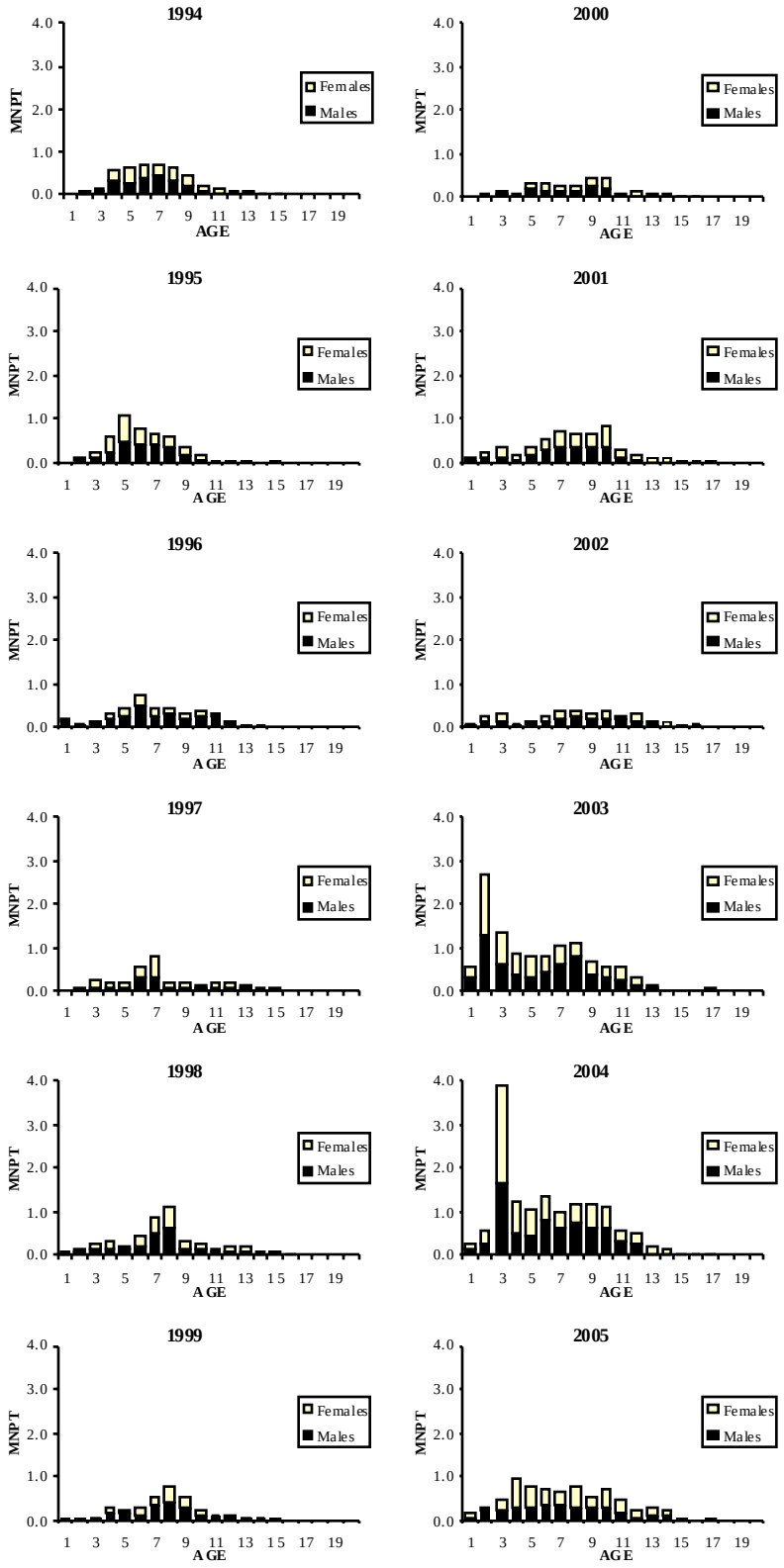

Fig. 3. Annual age composition by sex in Flemish Cap 1994-2005.

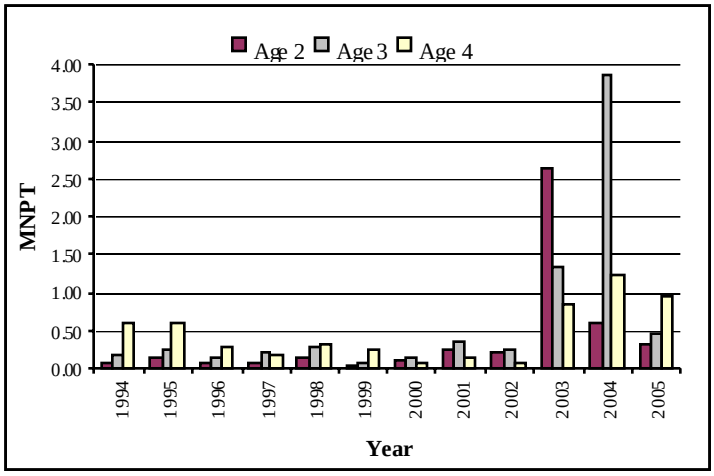

Fig. 4. Mean number per tow of age 2, age 3 and age 4 during the during the EU Flemish Cap bottom trawl survey (1988-2005).

Fig. 5. Female ratio by age in Flemish Cap 1994-2005.

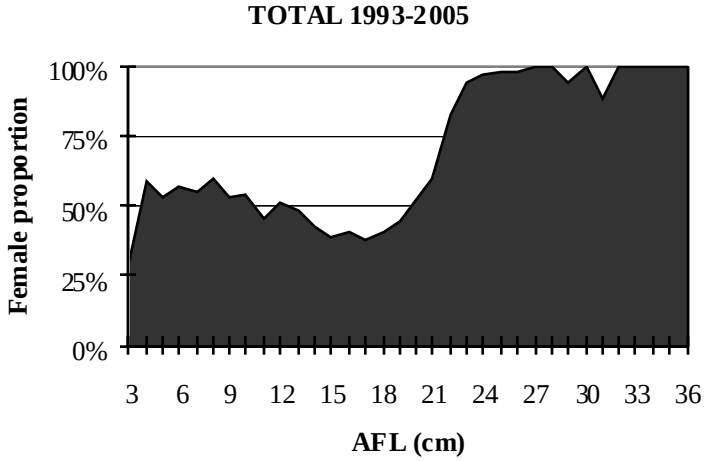

Fig. 6. Female ratio by length in Flemish Cap 1993-2005.

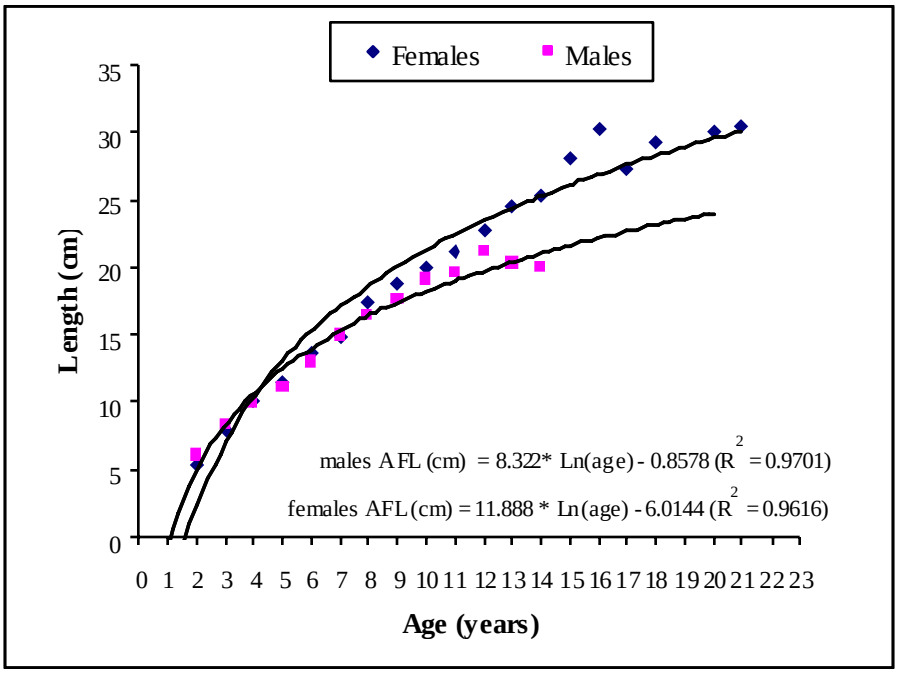

Fig. 7. Logarithmic growth curve by sexes in Flemish Cap 2005.

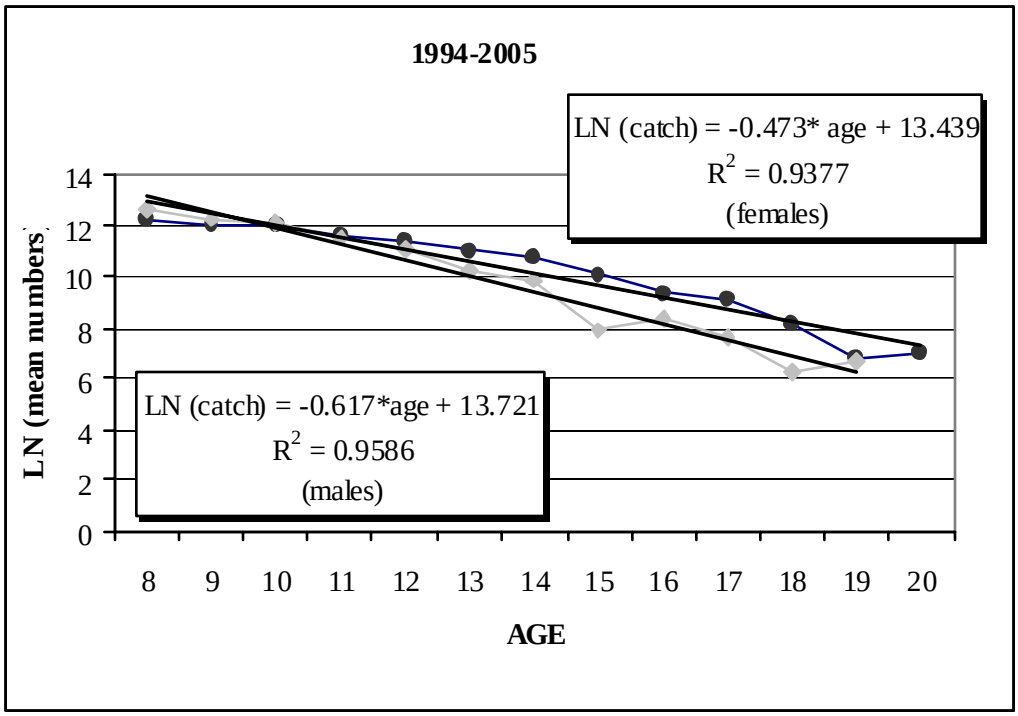

Fig. 8. Catch curves by sex for roughhead grenadier in Flemish Cap 1994-2005.

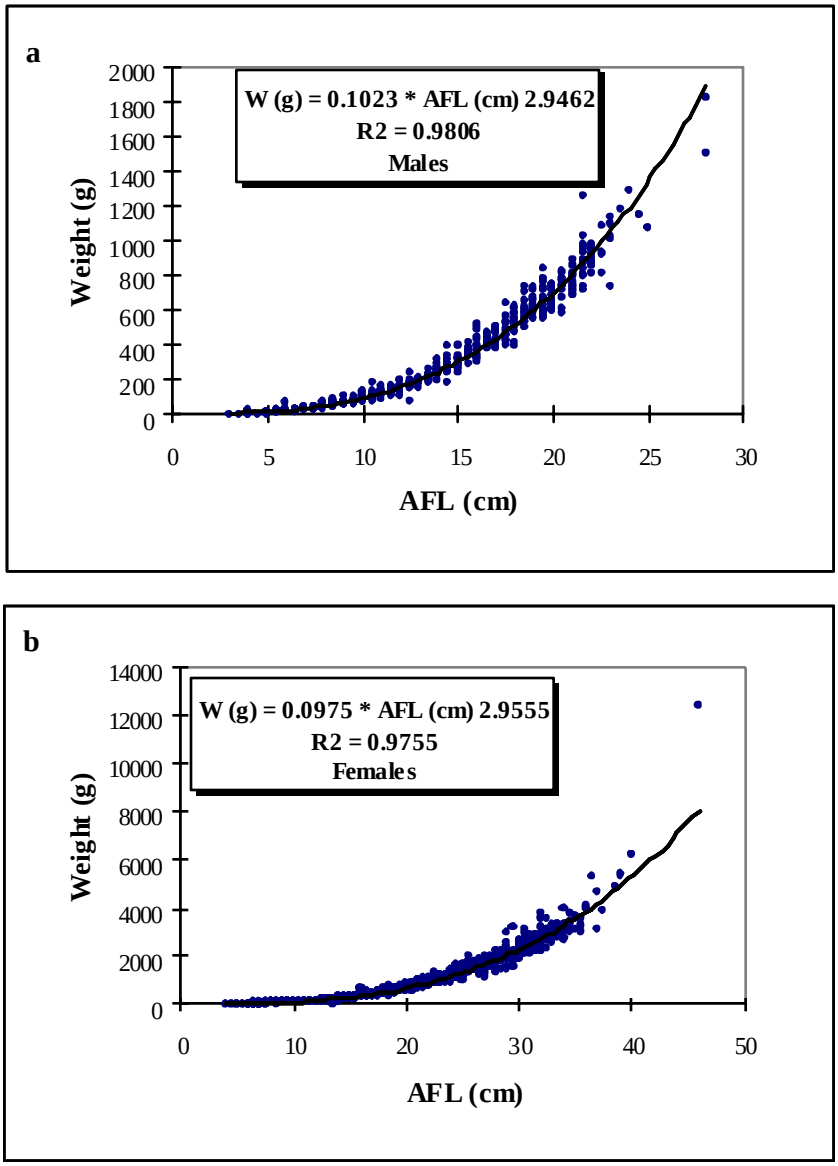

Fig. 9. Length weight relationship for (a) males and (b) females of roughhead grenadier in 2005.