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A Review on Roughhead Grenadier (*Macrourus berglax*) Biology and Population Structure on Flemish Cap (NAFO Division 3M), 1991-2002 Based on 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 Div. 3M) in the 200-720 m depth range. The information on roughhead grenadier population structure recorded during the last 12 EU surveys (1991-2002) in Flemish Cap is studied. 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 classes.

Results show that *M. berglax* 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 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 *M. berglax* 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 3 118 tons in 2001.

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.

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 (2001 and 2002) from

otolith readings of specimens captured in NAFO Div. 3LM. 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 1991-2002. The results are presented taking into account that the survey only covers the shallowest distribution area of *M. berglax*.

MATERIAL AND METHODS

Data on *M. berglax* for the 1991-2002 period were collected on the annual random-stratified bottom trawl surveys carried out by the European Union on the area (Vázquez, 2002). Data on age structure and sex-ratio are only available for the 1994-2002 period. Otolith sampling began in 1994, and since then a total of 4 273 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 are 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 reaching the second highest level of 2 473 tons in the period studied. Biomass decreased in 2002 to the level of 1 440 tons. Mean catch per trawl by strata and whole bank data are presented in Table 2. The results indicate that roughhead grenadier occupy 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 1991-2002 period. Captures are dominated by the 14-20 cm length classes, 55% of the total catch. The average AFL for both sexes is 15.4 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).

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 25 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 1993-2002 period in Flemish Cap was 16.9 cm, while mean AFL for males was 15.3 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 1994-2002, as well as mean length at age and standard deviation, are given by sex in Table 4. Mean length at age 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 5 shows age composition by sexes for *Macrourus berglax* in Flemish Cap in 1993-2002. The oldest male and female found in the study period was 20 years old. Mean age for females in Flemish Cap in the 1993-2002 period was 8.1 years, while mean age for males was 7.5 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 have declined sharply during last 4 years and the 1990-91 cohorts now dominates captures, although their importance has declined in 2002 since new year-classes recruited to the population.

Female-ratio in the whole study period is 52%. 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). 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 nine years (1994-2002). Both sexes are fully recruited at age 7 and the mortality obtained was different for bots sexes: 0.24 for females and 0.45 for males (Fig. 7).

Length-weight relationship 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 2002 survey.

Data available shows that *M. berglax* 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 is 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.

REFERENCES

ATKINSON, D.B. 1991. Relationships between pre-anal fin length and total length of roughhead grenadier (*Macrourus berglax* Lacépède) in The Northwest Atlantic. *J. Northw. Atl. Fish. Sci.*, **11**: 7-9.

CASAS, J.M. 1994. Age structure of roughhead grenadier (*Macrourus berglax*) on Flemish Cap, 1994. *NAFO SCR Doc.*, No. 80, Serial No. N2459, 5 p.

DE CARDENAS, E., J.M. CASAS, R. ALPOIM and H. MURUA. 1996. Preliminary results of the European long-line survey in the NAFO Regulatory Area. *NAFO SCR Doc.*, No. 34 Serial No N2709, 6 p.

ELIASSEN, J.E. 1983. Occurrence, gonad development and age distribution of the roughhead grenadier (Macrourus berglax Lacepede) (Gadiformes, Macrouridae) along the Continental slope of northern Norway. *ICES, Demersal Fish Committee*, C.M. 1983 /G:41.

GORDON, J. D. M. and BERGSTAD, O. A. (1992). Species composition of demersal fish in the Rockall Troug, north-eastern Atlantic, as determined by different trawls. *Journal of Marine Biological Association of the United Kingdom*, **72**: 213-230.

HUREAU, J.C., P. GEISTDORFER, and M. RANNOU. 1979. The cology of deep-sea benthic fish. *Sarsia*, **64** (1-2):103-108.

JORGENSEN, O.A. 1996. Distribution and Biology of Grenadiers (Macrouridae) in West Greenland Waters. *J. Northw. Atl. Fish. Sci.* **18**: 7-29

JUNQUERA, S., A VAZQUEZ, H. MURUA, E. ROMAN and J. L. DEL RIO. 2001. Spanish Research Report for 2000. *NAFO SCS Doc.*, No. 18, Serial No. 4402, 24 p.

MARQUARDT, D. W. 1963. An algorithm for least-squares estimation of nonlinear parameters. *Journal for the Society of Industrial and Applied Mathematics*, **11**, 431-441.

MERRETT, N. R., HAEDRICH, R. L., GORDON, J. D. M. & STEHMANN, M. (1991). Deep demersal fish assemblage structure in the Porcupine Seabight (eastern North Atlantic): results of single warp trawling at lower slope to abyssal soundings. *Journal of the Marine Biological Association of the United Kingdom*, **71**: 359-374.

MURUA, H. 2001. A review on Roughhead Grenadier (*Macrourus berglax*) Biology and population structure on Flemish Cap (NAFO Div. 3M) 1991-2000. *NAFO SCR Doc.*, No. 30, Serial No N4404, 19 p.

MURUA, H. 2002. A review on Roughhead Grenadier (*Macrourus berglax*) Biology and population structure on Flemish Cap (NAFO Div. 3M) 1991-2000. *NAFO SCR Doc.*, No. 18, Serial No 4619, 18 p.

RODRÍGUEZ-MARÍN, E., M. RUIZ, and A. SARASUA. 2002. Validation of roughhead grenadier (*Macrourus berglax*) otolith reading. *J. Appl. Ichthyology* **18**: 70-80.

SAVVATIMSKY, P.I. 1971. On age readings in grenadiers (Macrouriformes). *Vopr. Ikhtiol.*, **11**(3): 495-501.

SAVVATIMSKY, P.I. 1984. Biological aspects of roughhead grenadier (*Macrourus berglax*) from longline catches in the eastern Grand Bank area, 1982. *NAFO Sci. Coun. Studies*, **7**: 45-51.

SAVVATIMSKY, P.I. 1989. Investigations of Roughhead Grenadier (*Macrourus berglax* L) in the Northwest Atlantic, 1967-83. *NAFO Sci. Coun. Studies*, **13**: 59-75.

SAVVATIMSKY P.I. 1994. Age structure of roughhead grenadier (*Macrourus berglax*) in the Northwest Atlantic, 1985. *NAFO Sci. Coun. Studies,* **20**: 53-64.

SCOTT, W. B., and M. G. SCOTT. 1988.. Atlantic fishes of Canada. *Can Bull. Fish. Aquat. Sci.*, 219, 731 p.

SNELGROVE, P.V.R. and R.L. HAEDRICH. 1985. Structure of the deep demersal fish-fauna off Newfoundland. *Mar. Ecol. Prog. Ser.*, **27**: 99-107

VAZQUEZ, A. 2002. Results from the bottom trawl survey of Flemish Cap in July 2001. *NAFO SCR Doc*., No. 12, Serial No. N4613, 43 p.

WHEELER, A. 1969. The fishes of the British Isles and Northwest Europe: Anacanthini (p. 255.259). MacMillan and Co. Ltd., London England, 613 p.

Table 1.- Total biomass of roughhead grenadier estimated by the swept area method by strata during the EU bottom survey (1988-2002).

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

Table 2.- Mean catch per trawl by strata and whole bank (1991-2002).

			Average weight per trawl (Kg.)											
Strata	Area	Depth (m)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1 – 6	467	125-252					0.16	0.68						
7	108	253-360		0.01								0.05		
8	82	253-360	0.02					0.26	0.06		0.14			0.04
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	
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
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
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
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
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
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
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
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
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
Nº of valid tows			117	117	101	116	121	117	117	119	117	120	120	120

Table 3.- Roughhead grenadier length distribution and mean AFL (,000) for each year of the 1991-2002 period.

AFL (cm)/Year	91	92	93	94	95	96	97	98	99	00	01	02	Prop. (%)
3	7	29	0	0	0	7	7	113	21	7	147	90	0,83
4	14	104	104	0	37	59	35	33	18	33	27	36	1,28
5	24	321	379	47	45	215	16	95	27	71	229	202	3,84
6	33	82	120	31	46	63	52	65	24	49	80	83	2,34
7	77	120	515	65	60	31	111	57	17	38	81	111	2,87
8	25	57	226	169	72	56	98	66	23	38	149	109	2,30
9	41	37	112	98	139	46	76	208	35	65	74	62	2,15
10	40	36	182	231	342	113	94	177	93	27	57	22	3,15
11	97	49	156	196	295	116	31	121	205	86	95	46	3,19
12	215	53	200	117	527	160	173	155	102	105	133	51	4,38
13	253	98	177	100	271	255	195	217	141	145	161	83	4,66
14	275	259	307	255	131	308	395	496	190	171	388	170	7,03
15	208	298	560	236	185	212	317	577	324	127	402	196	7,97
16	221	256	890	213	275	308	208	489	447	295	442	288	9,40
17	271	187	715	426	332	244	90	345	394	296	392	249	8,49
18	315	197	613	469	412	244	127	197	330	218	524	215	8,41
19	266	155	505	440	433	308	163	215	201	224	444	269	7,46
20	226	210	364	248	280	270	148	159	142	146	356	204	5,79
21	86	112	282	166	151	114	107	144	128	103	209	178	3,53
22	81	81	193	101	73	101	113	157	47	88	93	101	2,50
23	45	74	244	71	16	31	83	50	55	37	80	70	1,82
24	31	35	95	73	26	46	82	88	32	39	86	29	1,43
25	0	35	50	72	26	21	45	68	39	37	104	35	1,25
26	22	62	78	43	19	29	52	38	0	37	46	24	1,05
27	16	29	31	24	28	21	53	23	9	8	49	36	0,68
28	25	29	58	8	13	8	22	7	14	13	64	8	0,66
29	16	21	58	46	0	0	15	23	8	7	16	30	0,57
30	16	44	17	19	9	8	0	17	25	7	45	8	0,58
31	0	10	0	31	6	7	7	0	0	7	15	0	0,21
32	0	14	0	11	7	14	8	0	0	0	8	0	0,15
33	0	0	0	0	0	0	0	0	0	0	0	7	0,00
34	0	0	0	0	0	0	0	7	0	8	0	8	0,03
35	0	0	0	0	0	0	0	0	0	7	0	0	0,01
Total	**2946**	**3094**	**7231**	**4006**	**4256**	**3415**	**2923**	**4407**	**3091**	**2539**	**4996**	**3020**	**100**
Mean AFL (cm)	**16,03**	**15,04**	**15,31**	**16,45**	**15,04**	**15,24**	**15,81**	**15,13**	**16,04**	**16,14**	**16.00**	**15.35**	**15,61**

Table 4.- Mean Age-Length key (1994-2002).

Males																				
Length / Age	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**20**	**Total**
3	13	1																		**14**
4	2	5																		**7**
5		19																		**19**
6		20	9																	**29**
7		1	21																	**22**
8		3	23	5																**31**
9		1	22	21	2															**46**
10			7	32	12															**51**
11			2	24	32	2														**60**
12			1	4	38	21	7													**71**
13				2	19	41	17													**79**
14					16	38	28	11	1											**94**
15					2	25	34	25	7											**93**
16					3	17	39	36	27	7	1									**130**
17						9	23	30	29	27	3									**121**
18						1	10	28	30	31	18	5	3	1	1					**128**
19							6	13	28	29	25	15	4	2	1		1			**124**
20								3	17	23	19	27	7	3	1					**100**
21								1	9	6	13	20	7	5	1	3	2			**67**
22										2	2	5	2	2					1	**14**
23													1	2				1		**4**
24														1					1	**2**
Total	**15**	**50**	**85**	**88**	**124**	**154**	**164**	**147**	**148**	**125**	**81**	**72**	**24**	**16**	**4**	**3**	**3**	**1**	**2**	**1306**
%	**1.1**	**3.8**	**6.5**	**6.7**	**9.5**	**11.8**	**12.6**	**11.3**	**11.3**	**9.6**	**6.2**	**5.5**	**1.8**	**1.2**	**0.3**	**0.2**	**0.2**	**0.1**	**0.2**	**100**
Mean Length	**3.1**	**5.6**	**8.1**	**10.1**	**12.1**	**14.0**	**15.3**	**16.6**	**17.9**	**18.5**	**19.3**	**20.1**	**20.2**	**20.9**	**19.5**	**21.0**	**20.3**	**23.0**	**23.0**	**15.0**
St. Div.	**0.35**	**1.11**	**1.29**	**1.06**	**1.42**	**1.48**	**1.67**	**1.53**	**1.63**	**1.37**	**1.23**	**1.03**	**1.31**	**1.61**	**1.29**	**0.00**	**1.15**	**-**	**1.41**	

Table 4.- (continued)

Females	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	5																				**5**
4		10																			**10**
5		29																			**29**
6		21	11																		**32**
7		11	35																		**46**
8		2	36	8																	**46**
9			21	23	3																**47**
10			10	39	11																**60**
11			1	27	31	3															**62**
12				12	33	23	1	1													**70**
13				1	33	34	9	1	1												**79**
14					16	39	23	8													**86**
15					4	33	33	21	4	1											**96**
16					2	18	36	27	13	3											**99**
17						8	31	34	20	5											**98**
18							13	30	29	17											**89**
19							3	23	38	28	8	2									**102**
20								8	30	34	18	8									**98**
21								4	12	28	21	11	4								**80**
22									4	17	31	23	12	3							**90**
23									2	2	15	16	14	2	2						**53**
24									1	5	10	18	16	8	2						**60**
25										1	6	8	16	18	4	1					**54**
26										1	1	12	10	6	7	3					**40**
27										1	1	1	8	11	8	3	2				**35**
28													3	10	6	2	1				**22**
29												1	1	2	4	7	1	2			**18**
30											1		1	4	7		4				**17**
31															2	1		2		1	**6**
32												1		1	1	1	1				**5**
34																		1		1	**2**
35																1		1			**2**
Total	**5**	**73**	**114**	**110**	**133**	**158**	**149**	**157**	**154**	**143**	**112**	**101**	**85**	**65**	**43**	**19**	**9**	**6**	**1**	**2**	**1639**
%	**0.3**	**4.5**	**7.0**	**6.7**	**8.1**	**9.6**	**9.1**	**9.6**	**9.4**	**8.7**	**6.8**	**6.2**	**5.2**	**4.0**	**2.6**	**1.6**	**0.6**	**0.4**	**0.1**	**0.1**	**100**
M. AFL	**3.0**	**5.5**	**7.9**	**10.1**	**12.2**	**14.0**	**15.7**	**17.1**	**18.7**	**20.1**	**21.9**	**23.1**	**24.4**	**26.1**	**27.4**	**28.4**	**29.2**	**31.2**	**35.0**	**32.0**	**17.0**
St. Dv.		**1.00**	**1.14**	**1.12**	**1.41**	**1.45**	**1.47**	**1.76**	**1.77**	**1.91**	**1.85**	**2.15**	**1.96**	**2.11**	**2.22**	**2.22**	**1.64**	**19.47**		**39.62**	

Table 5.- Roughhead grenadier age composition (,000) in Flemish Cap 1993-2002.

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

	1998			1999			2000			2001			2002		
Age	**M**	**F**	**Tot**	**M**	**F**	**Tot**	**M**	**F**	**Tot**	**M**	**F**	**Tot**	**M**	**F**	**Tot**
1	26	13	39	10	0	10	0	0	0	62	13	75	37	6	43
2	63	130	193	0	36	36	30	62	92	170	161	331	133	118	251
3	119	135	254	20	34	54	61	46	107	94	185	279	109	145	254
4	125	121	246	128	81	209	43	29	72	54	80	134	15	43	58
5	90	49	139	108	83	191	106	124	230	111	128	239	60	44	104
6	141	201	342	92	153	245	145	142	287	214	245	459	72	111	183
7	411	322	733	303	143	446	111	114	225	270	266	536	138	148	286
8	549	410	959	383	278	661	149	125	274	287	231	518	167	128	295
9	125	155	280	274	210	484	260	159	419	325	264	589	139	124	263
10	156	120	276	131	113	244	169	187	356	339	480	819	130	184	314
11	101	73	174	87	55	142	19	67	86	83	214	297	149	109	258
12	99	149	248	48	59	107	43	78	121	76	94	170	125	189	314
13	60	147	207	25	49	74	15	51	66	8	97	105		58	58
14	34	68	102	35	47	82	12	40	52	8	132	140	37	69	106
15		61	61	5	39	44	8	22	30	7	61	68	10	16	26
16		31	31		4	4	31	29	60	8	98	106	34	57	91
17		15	15												
18+															
Total	**2099**	**2200**	**4299**	**1649**	**1384**	**3033**	**1202**	**1275**	**2477**	**2116**	**2749**	**4865**	**1355**	**1549**	**2904**
M. Age	**7,53**	**8,12**	**7,83**	**7,92**	**8,19**	**8,04**	**7,92**	**8,34**	**8,14**	**7,33**	**8,47**	**7,97**	**7.8**	**8.5**	**8.2**
S.D.	**2,74**	**3,58**	**3,21**	**2,35**	**2,96**	**2,65**	**2,87**	**3,30**	**3,11**	**2,56**	**3,29**	**2,98**	**3.69**	**3.83**	**3.78**

Table 6a. Logarithmic growth regression curves, fitted to mean length at age data, for male and female roughhead grenadier from EU Survey (1993-2002).

	MALES		FEMALES	
Year	Regression	r^2	Regression	r^2
1993	AFL (cm) = 8.8156 Ln (A) - 1.8999	0.9861	AFL (cm) = 12.999 * Ln (A) - 8.6786	0.9794
1994	AFL (cm) = 13.034 Ln (A) - 8.1095	0.9241	AFL (cm) = 12.394 * Ln (A) - 5.4082	0.9412
1995	AFL (cm) = 8.8152 Ln (A) - 0.2014	0.9509	AFL (cm) = 12.268 * Ln (A) - 5.1506	0.9503
1996	AFL (cm) = 8.9440 Ln (A) - 1.6428	0.9911	AFL (cm) = 12.241 * Ln (A) - 6.1702	0.9551
1997	AFL (cm) = 8.7078 Ln (A) - 1.6519	0.9925	AFL (cm) = 12.118 * Ln (A) - 6.4209	0.9546
1998	AFL (cm) = 7.1799 Ln (A) + 1.3319	0.9678	AFL (cm) = 9.5935 * Ln (A) - 1.4863	0.9183
1999	AFL (cm) = 7.4754 Ln (A) + 1.1001	0.9621	AFL (cm) = 9.6124 * Ln (A) - 1.1061	0.9240
2000	AFL (cm) = 7.835 * Ln (A) – 0.0057	0.9896	AFL (cm) = 12.923 * Ln (A) – 7.6958	0.9331
2001	AFL (cm) = 7.266*Ln (A) + 1.4463	0.975	AFL (cm) = 10.291* Ln (A) – 1.9577	0.9422
2002	AFL (cm) = 7.0786 *Ln (A) + 1.2645	0.973	AFL (cm) = 10.551* Ln (A) – 2.5121	0.913

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 1993-2002.

	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

Table 7. Length weight relationship for roughhead grenadier males and females from EU Survey (1993-2002).

	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

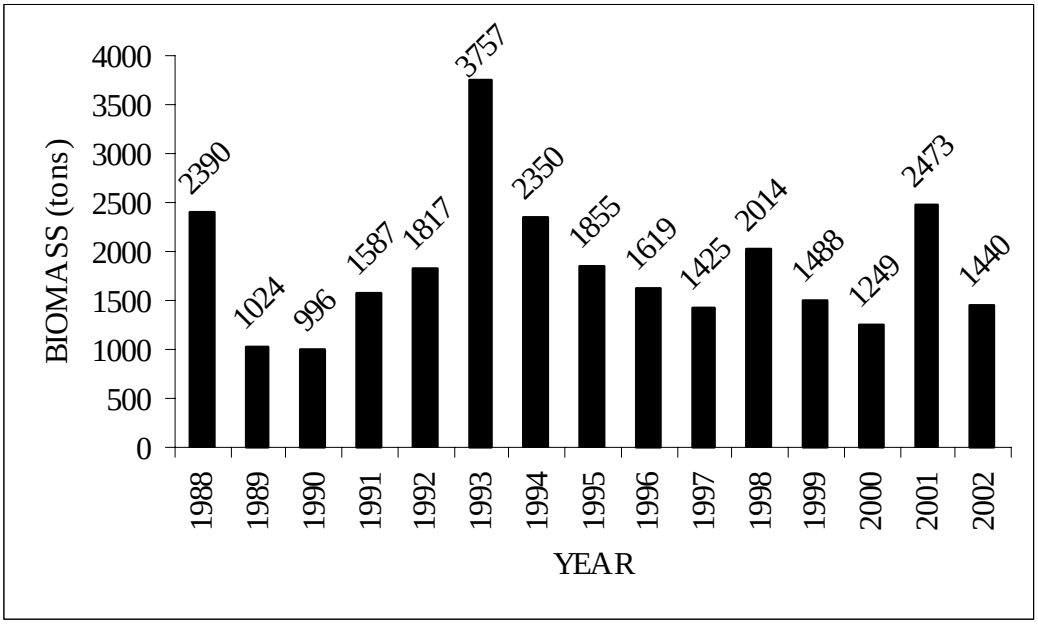


Fig. 1. Total biomass estimated by the swept area method for the area studied during the EU bottom trawl survey (1988-2002).

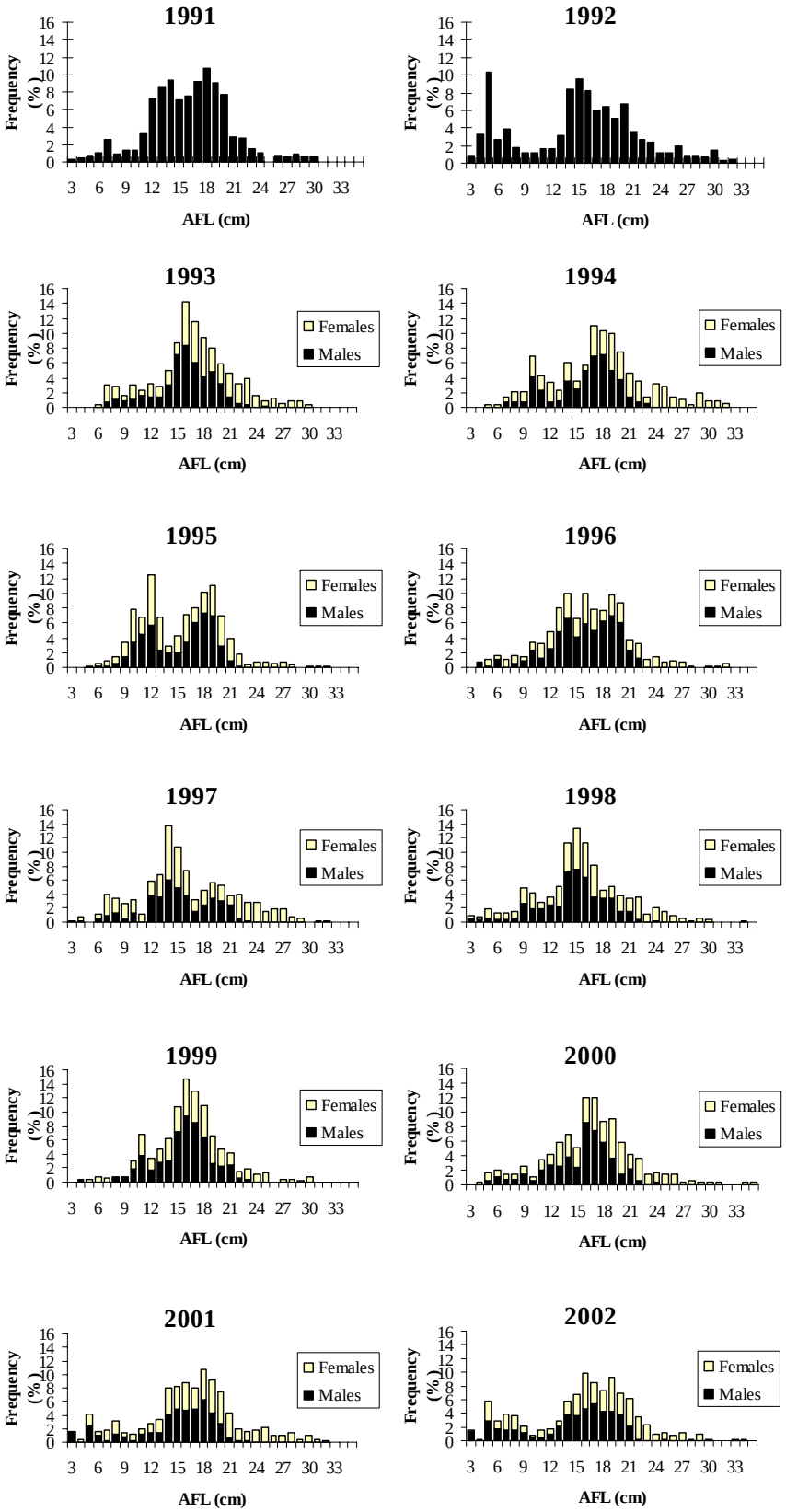


Fig. 2. Annual length distribution by sex (except 1991-1992) in Flemish Cap 1991-2002.

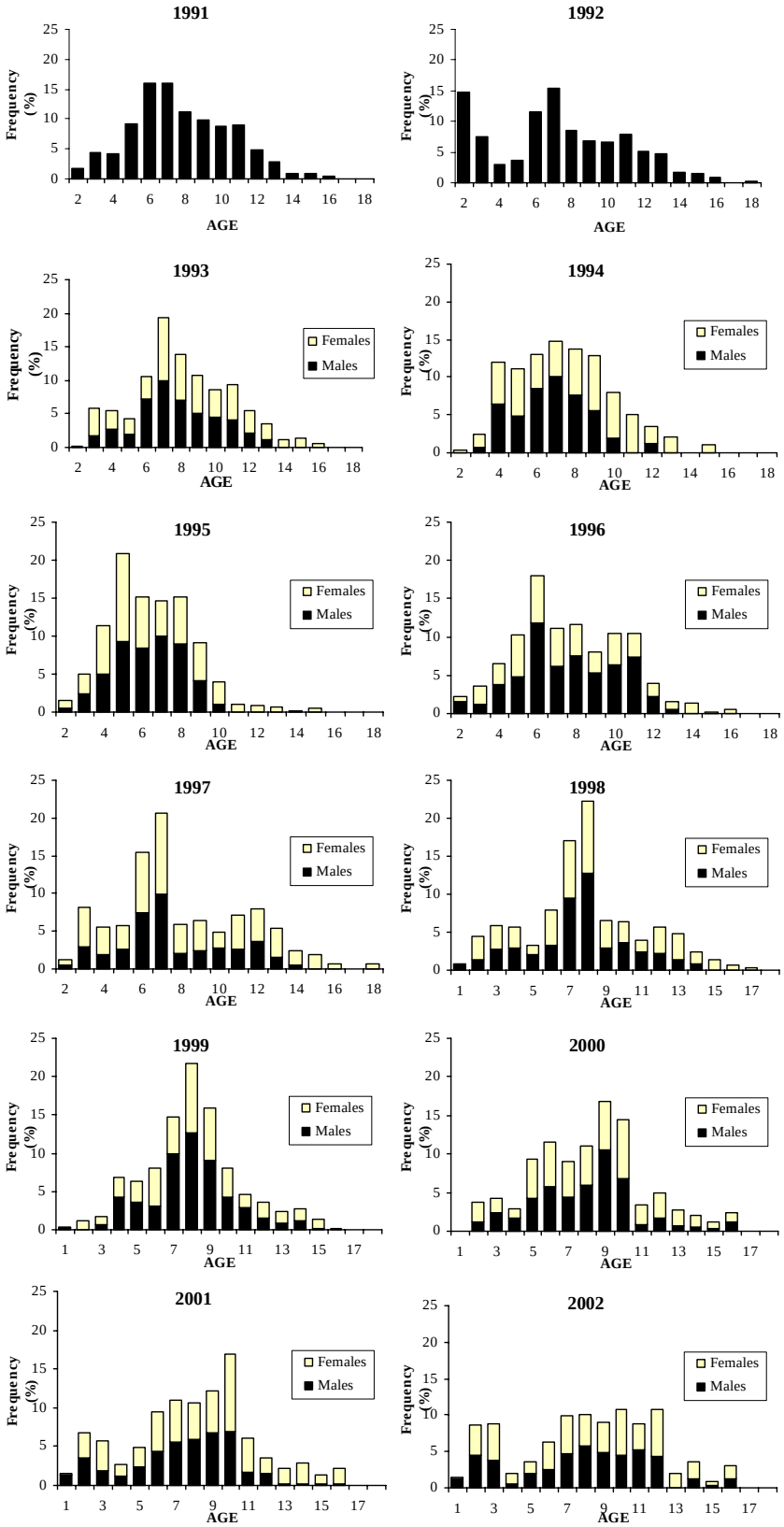
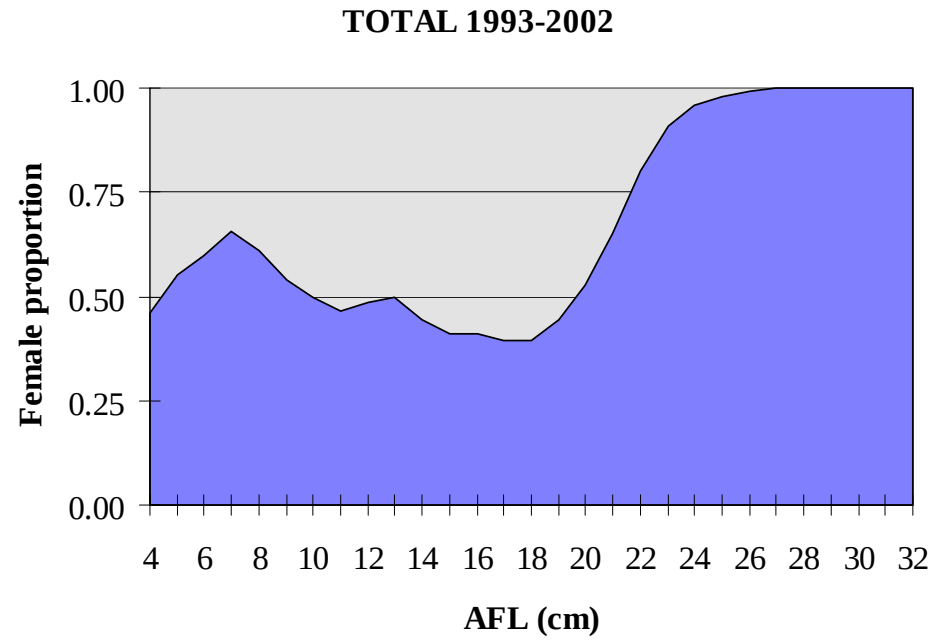


Fig. 3. Annual age composition by sex (except 1991-1992), in Flemish Cap 1991-2002.



Fig, 4. Female ratio by age in Flemish Cap 1993-2002.

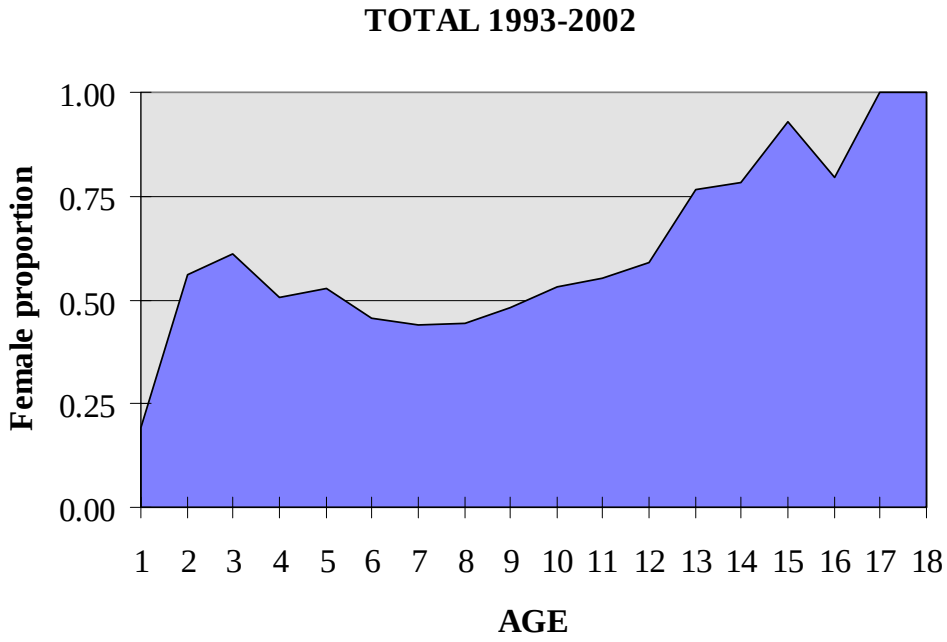


Fig. 5. Female ratio by length in Flemish Cap 1993-2002.

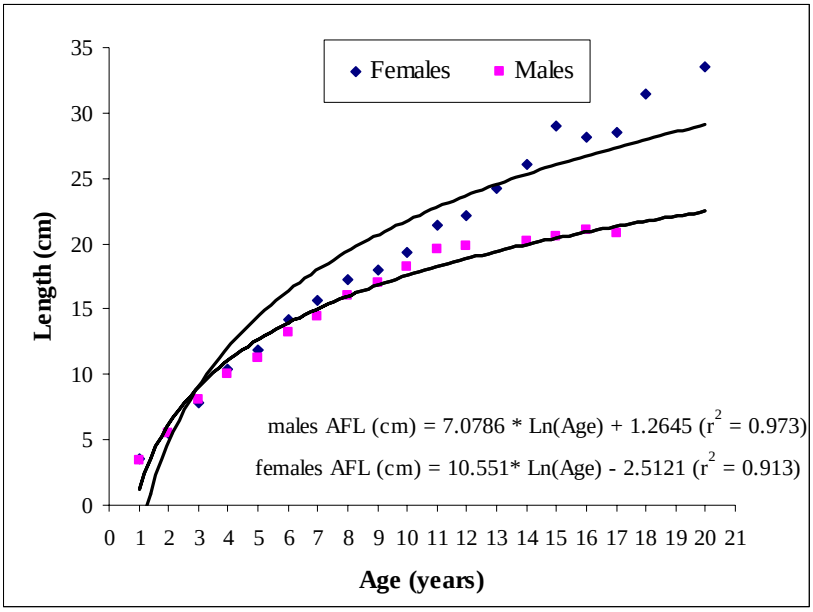


Fig. 6. Logarithmic growth curve by sexes in Flemish Cap 2002.

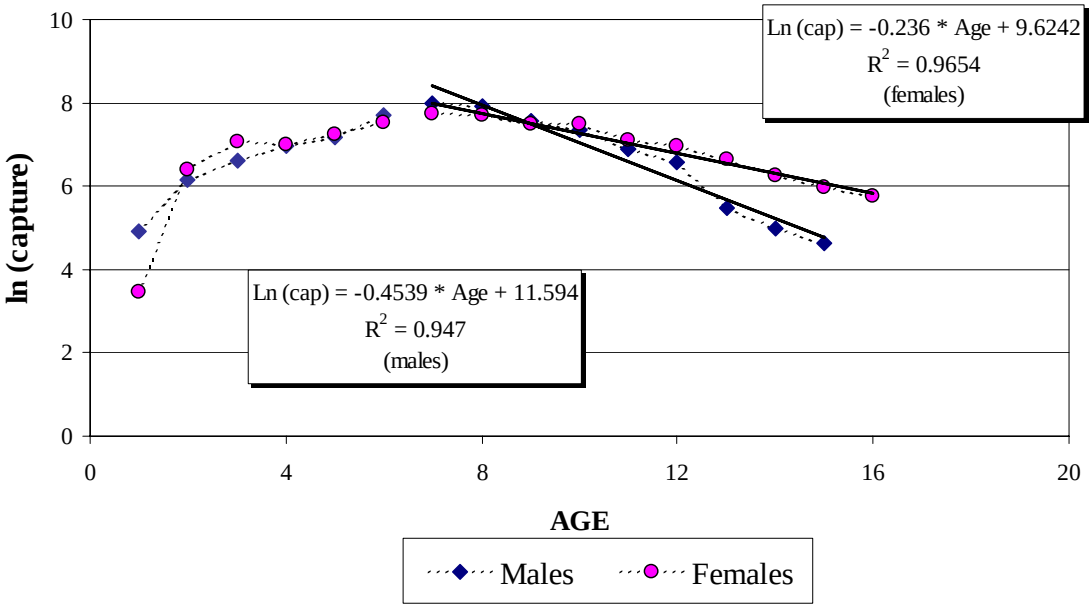


Fig. 7. Catch curves by sex for roughhead grenadier in Flemish Cap 1994-2002.

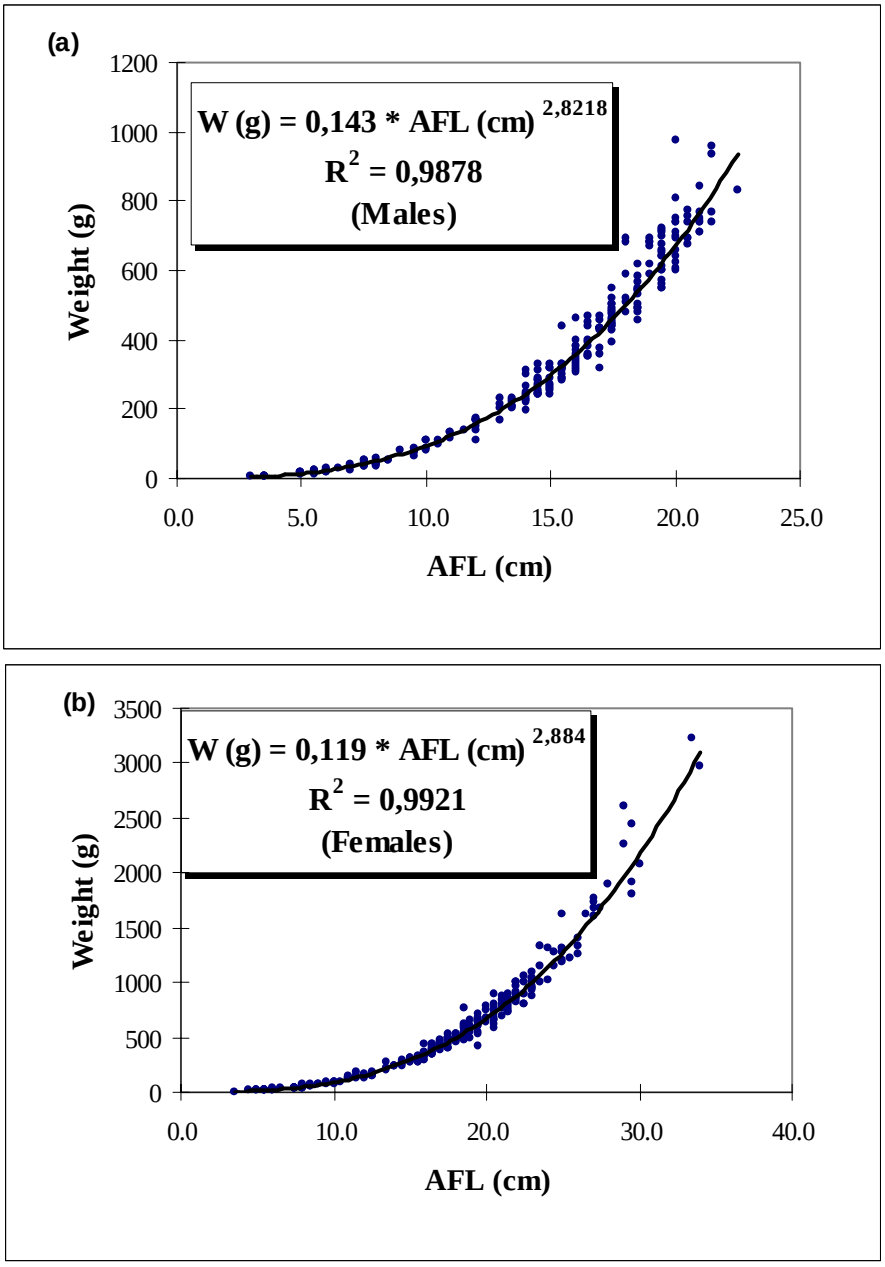


Fig. 8. Length weight relationship for males (a) and females (b) of roughhead grenadier in 2002.