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A Review of Roughhead Grenadier (*Macrourus berglax*) Population Structure on Flemish Cap (NAFO Division 3M), 1991-1997

by

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ABSTRACT

Since 1998 European Union has conducted an annual bottom trawl survey in Flemish Cap (NAFO Div. 3M) in the 200-720 m depth range. Roughhead grenadier (*Macrourus berglax*) is considered a target species within this project and its population structure is being studied.

A review of the information on roughhead grenadier recorded during the last 7 EU surveys (1991-1997) in Flemish Cap is presented in this paper. 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 and they disappear from the capture in largest length classes. Capture is dominated by the 6-8 age-classes.

The 1986-1987 cohorts dominated the catches during the first years. 1982 cohort seems also abundant. The importance of these annual classes has declined sharply during last 4 years and the abundant 1990 cohort now dominates captures.

The oldest male found was 14 years old, while oldest female was 18 years old. For larger classes, females grow faster than do males. 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 1200 m, although they may inhabit depths between 200-2000 m (Snelgrove and Haedrich, 1985; Cardenas *et al.* 1996), and it has been found in depths up to 2700 m (Wheeler, 1969). The population dynamics and biology of *M. berglax* has been proved difficult to study due to its distribution in great depths and its relatively little importance as a commercial species in the Northwest Atlantic (Casas, 1994).

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 traditional fisheries. The impact of the fishing pressure is unknown at present (Atkinson, 1996).

Spain has been developing a deep-water trawl fishery in the NAFO Regulatory Area since 1990, with Greenland halibut as target species. The fleet started operating in the northern area of Flemish Pass, but has gradually extended the area of its activities and now fishes in practically all the continental slope of the NAFO Regulatory Area (Cardenas, 1996). At the beggining of the fishery, grenadiers (*Coryphaenoides rupestris* and *Macrourus berglax*) were usually discarded. Since then, its commercial importance increased and it has become the main component in the by-catch of the Spanish and Portuguese Greenland halibut fishery (Paz and Iglesias, 1994; Alpoim *et al.*, 1997). Roughhead grenadier makes up 6% of the total Spanish bottom trawl catch and 8% when discards are taken into account (Rodríguez-Marín *et al.*, 1998). These percentages increase with depth, as also reported Gorchinsky and Savvatimsky (1996) in the Russian bottom trawl survey carried out in Flemish Pass area, were roughhead grenadier made up 25% of the catch in depths of 1202 - 1440 m. Total catches of roughheads in Div. 3LM averaged about 5100 t from 1991 to 1994 (Atkinson, *et al.* 1994).

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. Since 1994 *M. berglax* is considered a target species within this project and its population structure is being studied (Casas, 1994; Sainza, 1996; Alpoim, 1997; Sarasua *et al.*, 1998).

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 Divisions 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 Casas (1994), Sainza (1995, 1996), Alpoim (1997), Sarasua *et al.*, (1998) and Rodríguez-Marín *et al.*, (1998) from otolith readings of specimens captured in NAFO Divisions 3LM. Eliassen (1983) also performed age estimation by otolith reading from roughhead caught in the continental slope of Norway.

The population structure of roughhead grenadier on Flemish Cap in the period 1991-1997 is presented in this paper. The results are presented taking into account that the survey only covers the shallowest distribution area of *M. berglax*.

MATERIAL AND METHODS

Data were collected on the annual random-stratified bottom trawl surveys carried out by the European Union on the area. Methodology is described by Vázquez (1998). Data on *M.berglax* of the 1991-1997 period will be used in this paper. Data on age structure and sex-ratio are only available for the 1993-1997 period. Otolith sampling began in 1994, and since then a total of 1567 otoliths have been read. Annual length-age keys have been applied for each year. Otoliths were not sampled in 1993 and the mean 96-97 age-length key (the most consistent readings) has been applied to the 1993 data.

Otoliths were broken through the nucleus and read by transmited light (Casas, 1994). Many difficulties in reading Macrouridae age from otoliths and scales have been reported previously (Savvatimsky, 1984). It is more difficult to age deepwater fishes, since seasonal phenomena are not as pronounced as in the upper layers and rings are hardly visible on their body structures (Savvatimsky, 1994). 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.*, 1998).

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. Data are given in 1 cm intervals. Length is presented as anal-fin length (AFL). Total weight was recorded accurate to the nearest 10 g.

RESULTS AND DISCUSSION

Table 1 shows length distributions of roughhead grenadier for the 1991-1997 period. Captures are dominated by the 14-20 cm length classes, 53.7 % of the total catch. The average AFL for both sexes is 15,5 cm. This value is smaller than the values found by Savvatimsky (1994) and Cardenas *et al.* (1996). The former gives an average AFL of 19.8 cm (51.3 cm total length) for Div. 3K, and the latter gives a mean AFL of 21,1 cm (54,4 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 Table 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 (12% of catches) reaching 32 cm long. Average AFL for females is also greater than for males. Female mean AFL for the 1993-1997 period in Flemish Cap was 16.8 cm, while mean AFL for males was 15.6 cm. This sexual difference is consistent with data found before. 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 3KLN. Those differences have also been seen in the commercial fleet in 3LN, where females are larger than males on average (Godinho *et al.*, 1996).

The means AFL-age key for 1994-1997, as well as mean length at age and standard deviation are given by sex in Table 3. Mean length at age is similar for males and for 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 Divs. 0B, 2GH and 3K, the differences are of 0.5 years for males and of 1 year up to age 13, and higher beyond this age for females. Savvatimsky (1994) found that the differences between sexes in size at age come about from 10 years onwards.

Table 4 shows age composition by sexes for *Macrourus berglax* on Flemish Cap in 1993-1997. Females are more abundant in almost all year-classes, but differences increase in largest groups (>12 year-class). Only females appear in year-classes older than 14. The oldest male found in the study period was 14 years old, while oldest female was 18 years old. Savvatimsky (1994) and Jorgensen (1996) described similar growing pattern using scales for aging fish, but differentiation starts one year latter in their studies, as has been previously mentioned. This fact could be explained due to the different aging method used in their studies and in ours, or due to the different latitude of the sampling areas where the specimens were obtained, because temperature differences would cause slower growth, and a delay in reaching sexual maturity (Rodríguez-Marín *et al.*, 1998).

Sexual differences in the growing pattern seem to be related with reaching maturity (Cárdenas, 1996; Murua and Motos, 1997; Scott and Scott, 1988). Scott and Scott (1988) affirm that females grow faster than do males from first maturity in the following species: Atlantic halibut (*Hippoglossus hipoglossus*) and yellowtail flounder (*Limanda ferruginea*). Similar growth differences between sexes have been also found in megrim (*Lepidorhombus whiffiagonis*) (Landa *et. al.*, 1996) and anglerfish (*Lophius piscatorius*) (Alfonso-Dias *et. al.*, 1996). We also have to bear in mind that a greater longevity of females is not an uncommon phenomenon in many fish species, especially Pleuronectiforms (Scott & Scott, 1988). Mean age for females in Flemish Cap in the 1993-1997 period was 8.4 years, while mean age for males was 7.3 years. Savvatimsky (1994) for Div. 0B, 2GH and 3K found similar differences.

Interannual differences in length and age are shown in Figure 1. The 1986-1987 cohorts dominated the catches during the first years. 1982 cohort seems also abundant. The importance of these annual classes has declined sharply during last 4 years and the abundant 1990 cohort now dominates captures. The strength of this year-class has been seen in previous surveys (Alpoim, 1997) and it has been confirmed by the 1997 survey (Sarasua *et al.*, 1998).

Average length and age composition for the whole study period are presented in Figure 2 and Figure 3 respectively. The length and age range found during these 7 surveys are very similar to those cited before in the Northwestern Atlantic (3KLN). Chrzan (1969) gives values of 11.2-34.1 cm AFL and 2-17 years; Savvatimsky (1971) found values of 9.1-26 cm and 3-16 years; and Savvatimsky (1984), ranges of 15-34.9 cm and 6-23 years. Differences can be attributed to differences in depth and sampling gear.

Female-ratio in the whole study period is 52%. This value is lower that the one found by Cardenas *et al.* (1996) in 3LMN, where females made up 71,4% of the catch. However, this difference could be easily explained due to the different area covered by both surveys. As length increases with depth in many species (Cárdenas *et al.*, 1996; Junquera *et al.*, 1992), female ratio might also increase in deeper areas.

Figures 4 and 5 present sex-ratio by age and by length respectively, for the whole study period. In the sex-ratio by age, female proportion fluctuates around 54%-64% the first 12 years. It increases from age 13 upwards. Female-proportion reaches 70% in year-group 13 and 80% in

year-group 14. Females are 100% of the captures after that. Similar sex-ratio, with males being more abundant in the central part of the population, is described by Savvatimsky (1994) for Northwestern Atlantic.

Five different areas can be described in the sex-ratio by length figure. In the first length-classes (5-10 cm AFL), females are more abundant than males. This might be due to data scarcity or due to the great amount of specimens with indeterminated sex for those length-classes. Between 10-14 cm, sex-ratio fluctuates around 50%. After that, female-ratio decreases to around 40%. This fact is a result of the different growth rate between sexes. 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 (Rodríguez-Marín *et al.*, 1998). Therefore, male proportion increases in those central lengths. Data show that after this period, females proportion increases very fast and reaches 100% at length-classes over 25 cm AFL. The increment in the female-ratio can be due to three 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 age at length (Rodríguez-Marín *et al.*, 1998). And it seems that there are also some differences in mortality, since males disappear from the capture in larger length-classes.

Total mortality (Z) by sex was calculated from catch curves, fitting regression lines by sex to ages fully recruited to the survey. The catch curves (Figure 6) were elaborated from data for four years (1994-1997) (Table 4). Both sexes are fully recruited at age 7, and in fact a different mortality is obtained: 0.3 for females and 0.4 for males. The same fully recruited age and mortality differences between sexes have been found in the Spanish commercial bottom trawl fishery for this species, with practically identical values of Z (Rodríguez-Marín, pers. com.)

Data available show 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 these 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. Roughhead grenadier length distribution and mean AFL (,000) for each year of the 1991-1997 period.

	91	92	93	94	95	96	97	Proportion (%)
3	7	29	0	0	0	7	7	0,18
4	14	104	104	0	37	59	35	1,27
5	24	321	379	47	45	215	16	3,76
6	33	82	120	31	46	63	52	1,53
7	77	120	515	65	60	31	111	3,51
8	25	57	226	169	72	56	98	2,52
9	41	37	112	98	139	46	76	1,97
10	40	36	182	231	342	113	94	3,72
11	97	49	156	196	295	116	31	3,37
12	215	53	200	117	527	160	173	5,18
13	253	98	177	100	271	255	195	4,84
14	275	259	307	255	131	308	395	6,92
15	208	298	560	236	185	212	317	7,23
16	221	256	890	213	275	308	208	8,51
17	271	187	715	426	332	244	90	8,13
18	315	197	613	469	412	244	127	8,53
19	266	155	505	440	433	308	163	8,14
20	226	210	364	248	280	270	148	6,26
21	86	112	282	166	151	114	107	3,65
22	81	81	193	101	73	101	113	2,67
23	45	74	244	71	16	31	83	2,02
24	31	35	95	73	26	46	82	1,39
25	0	35	50	72	26	21	45	0,89
26	22	62	78	43	19	29	52	1,09
27	16	29	31	24	28	21	53	0,72
28	25	29	58	8	13	8	22	0,58
29	16	21	58	46	0	0	15	0,56
30	16	44	17	19	9	8	0	0,41
31	0	10	0	31	6	7	7	0,22
32	0	14	0	11	7	14	8	0,19
Total	**2946**	**3094**	**7231**	**4006**	**4256**	**3415**	**2923**	**100,00**
Mean AFL (cm)	**16,03**	**15,04**	**15,31**	**16,45**	**15,04**	**15,24**	**15,81**	**15,52**

Table 2. Length distribution (,000) and mean AFL by sex, Flemish Cap 1993-1997.

	1993		1994		1995		1996		1997		Total	
Length	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
3									7		7	0
4							23		7	14	30	14
5				9		6	7	24			7	45
6		17		8	6	16	31	16	15	15	58	88
7	45	142	17	15	9	26	0	31	29	82	109	322
8	70	104	17	32	22	31	16	32	39	59	186	289
9	60	44	17	32	57	76	30	16	16	60	237	304
10	67	115	92	65	128	171	70	37	40	54	525	613
11	100	39	54	42	175	89	38	62		31	542	352
12	89	111	16	60	217	267	76	71	107	59	722	835
13	91	86	19	32	89	169	149	100	100	95	537	651
14	184	123	81	54	73	34	205	103	171	224	787	572
15	435	109	55	24	79	88	127	79	139	170	914	558
16	520	362	111	17	130	145	183	125	106	102	1180	896
17	374	341	155	95	237	70	152	92	45	45	1200	713
18	256	332	162	69	281	112	191	45	69	58	1240	728
19	301	196	111	113	270	156	215	87	96	67	1263	775
20	202	162	84	85	112	156	185	85	88	60	783	704
21	92	190	33	70	32	119	73	41	70	37	332	576
22	34	159	17	62	9	58	37	64	14	99	120	500
23	26	218	14	19		16		31	7	76	47	376
24		95		73		26		46		82	0	348
25	9	41		63		26		21		45	9	222
26		78		32		19		29		52	0	229
27		31		24		28		21		53	0	185
28		58		8		13		8		22	0	122
29		58		46				0		15	0	119
30		17		19		9		8			0	62
31				20		6		7		7	0	46
32				11		7		14		8	0	47
Total	2955	3228	1055	1199	1926	1939	1808	1295	1165	1691	10835	11291
Mean AFL (cm)	15,93	17,57	15,95	18,57	15,25	15,70	15,78	16,57	15,01	16,71	15,57	16,79

Table 3. Mean Age-Length key (1994-1997).

MALES	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
3	1													1
4	4													4
5	1													1
6	3	4												7
7	1	7												8
8	2	8	4											14
9		6	9											15
10		4	17	5										26
11		2	10	9	1									22
12		1	1	15	14	1								32
13			2	14	17	4								37
14				12	19	7	1							39
15				2	17	12	3	1						35
16				2	14	19	9	4						48
17					9	16	8	5	4					42
18					1	10	16	10	7	5	2	1		52
19						6	12	16	11	8	4			57
20							3	12	11	8	10	2	1	47
21							1	9	4	6	5	3	1	29
22									2	2	3	1		8
23												1		1
	12	32	43	59	92	75	53	57	39	29	24	8	2	525
Mean AFL	5,4	8,3	10,0	12,6	14,3	16,2	17,7	18,9	19,3	19,7	20,1	20,8	20,5	
S.D.	1,61	1,55	1,15	1,44	1,63	1,63	1,47	1,51	1,30	1,17	1,09	1,39	0,50	

FEMALES	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
3																		0
4	2																	2
5	5																	5
6	3	5																8
7	4	14																18
8	1	15	6															22
9		8	14	1														23
10		3	20	5														28
11			13	12	1													26
12			8	15	10	1	1											35
13			1	17	15	4												37
14				12	14	5	2											33
15				4	17	9	6	1										37
16				2	11	13	5		1									32
17					6	18	9	3										36
18						12	12	7	1									32
19						3	15	17	4	2	1							42
20							7	15	11	5	1							39
21							4	11	10	6	1							32
22								4	13	10	6	2						35
23								2	2	7	4	2						17
24								1	5	7	6	6	1					26
25									1	6	2	4	3	2				18
26									1	1	8	3	1	4				18
27									1	1	1	5	6	2				16
28												3	3	1	1			8
29											1	1		2	1			5
30										1		1		2				4
31														1	1		1	3
32											1		1	1	1			4
	15	45	62	68	74	65	61	61	50	46	32	27	15	15	4	0	1	641
Mean AFL	5,8	7,8	10,1	12,5	14,3	16,2	17,8	19,7	21,4	22,7	24,2	25,6	26,9	27,8	30,0	-	31,0	
S.D.	1,17	1,07	1,21	1,51	1,53	1,62	1,93	1,59	1,98	2,15	2,55	2,06	1,82	2,17	1,58	-	-	

Table 4. Roughhead grenadier age composition (,000), Flemish Cap 1993-1997.

	1993			1994			1995		
Age	Males	Females	Total	Males	Females	Total	Males	Females	Total
2	0	8	8		9	9	20	38	58
3	112	248	359	17	36	53	92	104	196
4	173	162	335	143	121	264	190	247	437
5	120	151	271	108	139	247	360	443	803
6	445	207	652	187	101	288	324	259	583
7	621	570	1190	224	104	328	385	180	565
8	437	413	850	169	134	303	343	240	583
9	309	353	663	124	160	284	162	192	354
10	278	257	535	42	133	175	41	111	152
11	248	327	575		113	113		39	39
12	128	205	334	28	50	78		33	33
13	69	149	218		47	47		27	27
14	6	62	67			0		7	7
15	0	85	85		22	22		22	22
16		31	31			0			0
17			0			0			0
18			0			0			0
Total	**2946**	**3228**	**6174**	**1042**	**1169**	**2211**	**1917**	**1942**	**3859**
Mean Age	**7,79**	**8,39**	**8,10**	**6,79**	**7,93**	**7,39**	**6,33**	**6,57**	**6,45**
S.D.	**2,37**	**3,10**	**2,79**	**1,93**	**2,88**	**2,54**	**1,76**	**2,56**	**2,20**

	1996			1997			Total		
Age	Males	Females	Total	Males	Females	Total	Males	Females	Total
2	46	24	70	14	21	35	80	100	180
3	35	79	114	83	149	232	339	616	954
4	116	84	200	53	106	159	675	720	1395
5	149	172	321	73	89	162	810	994	1804
6	365	194	559	214	230	444	1535	991	2526
7	191	157	348	284	309	593	1705	1320	3024
8	232	127	359	59	110	169	1240	1024	2264
9	167	85	252	71	111	182	833	901	1735
10	199	127	326	78	63	141	638	691	1329
11	226	97	323	74	130	204	548	706	1254
12	68	52	120	103	127	230	327	467	795
13	15	34	49	44	110	154	128	367	495
14	0	44	44	15	55	70	21	168	188
15	0	5	5		56	56	0	190	190
16	0	14	14		18	18	0	63	63
17			0			0	0	0	0
18			0		18	18	0	18	18
Total	**1809**	**1295**	**3104**	**1165**	**1702**	**2867**	**8879**	**9336**	**18215**
Mean Age	**7,62**	**7,60**	**7,61**	**7,60**	**8,24**	**7,98**	**7,30**	**8,41**	**7,86**
S.D.	**2,53**	**3,09**	**2,78**	**2,84**	**3,60**	**3,33**	**2,38**	**3,14**	**2,81**

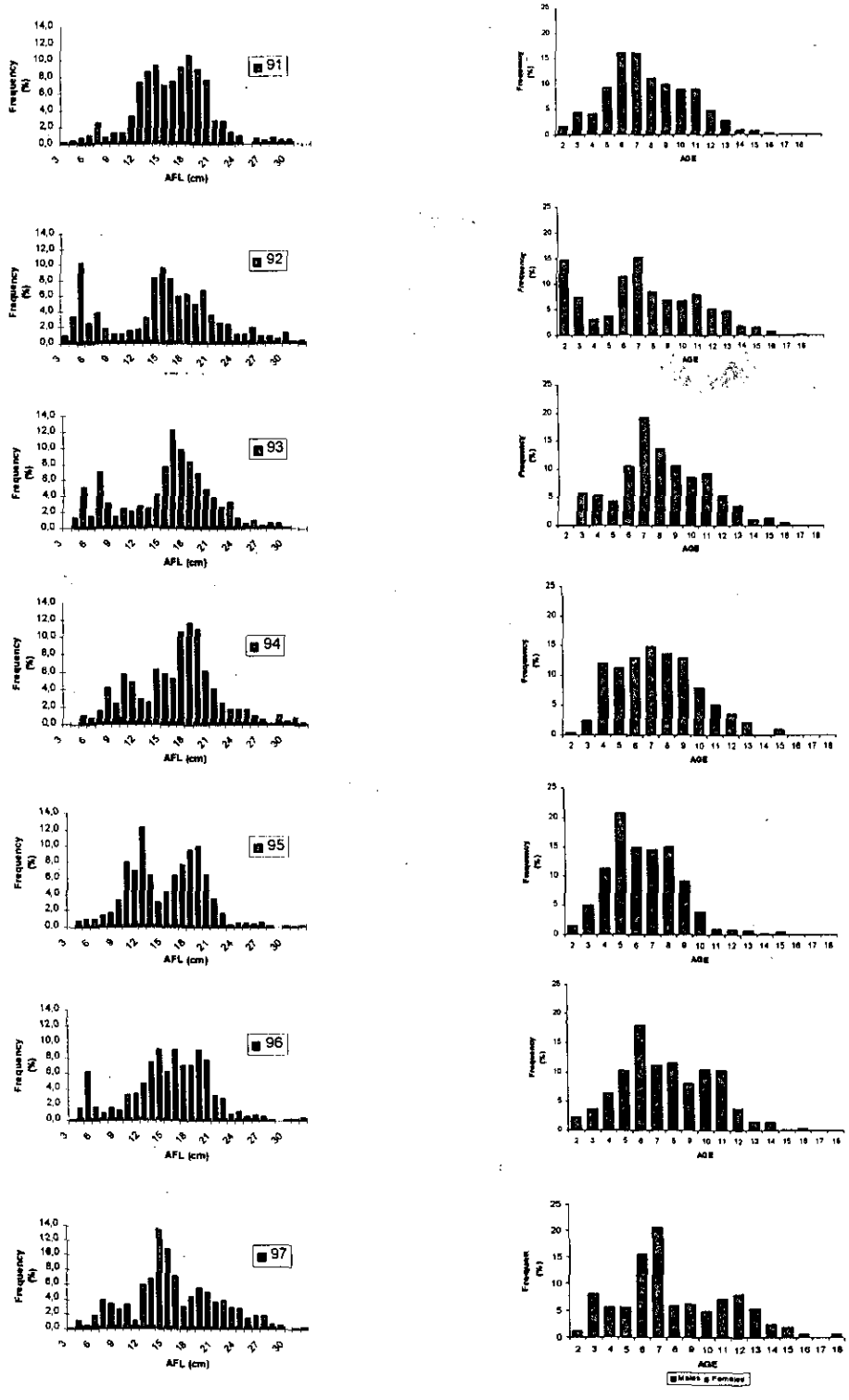


Figure 1. Annual length distribution and age composition, Flemish Cap 1991-1997.

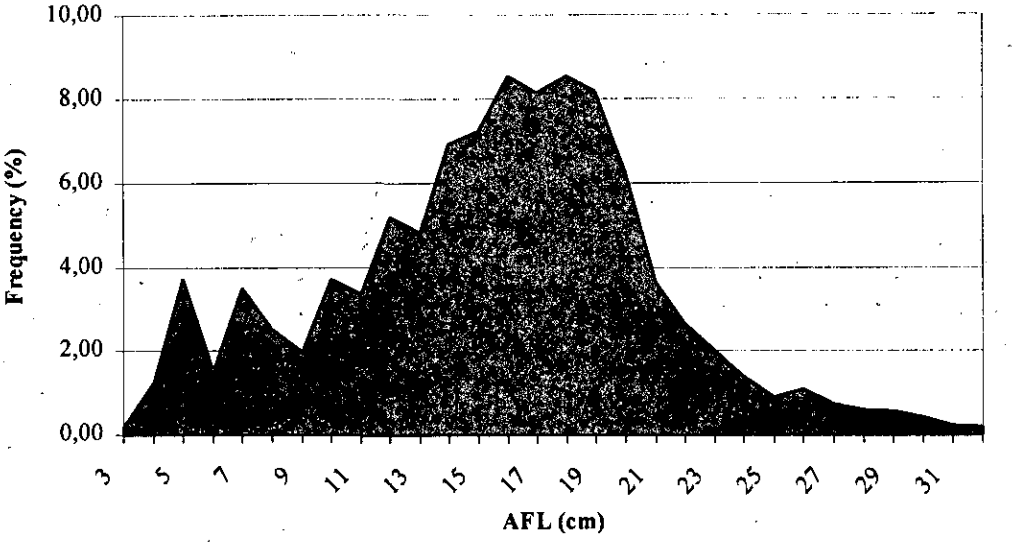
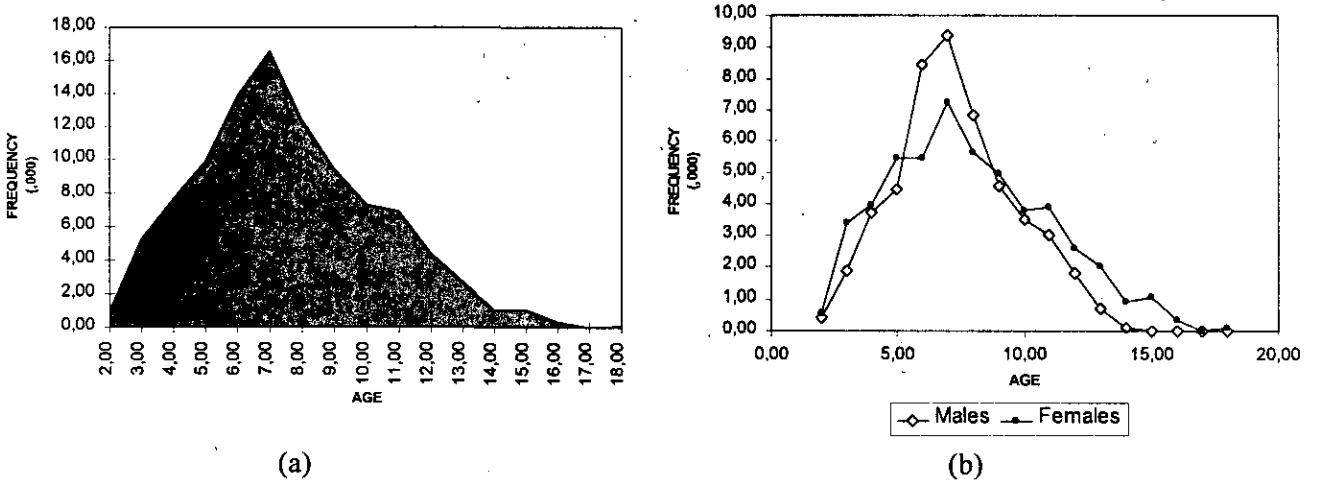


Figure 2. Average AFL for the 1993-1997 surveys.



(a) (b)

Figure 3. Average age distribution in the 1994-1997 surveys. (a) Both sexes together; (b) sex distribution.

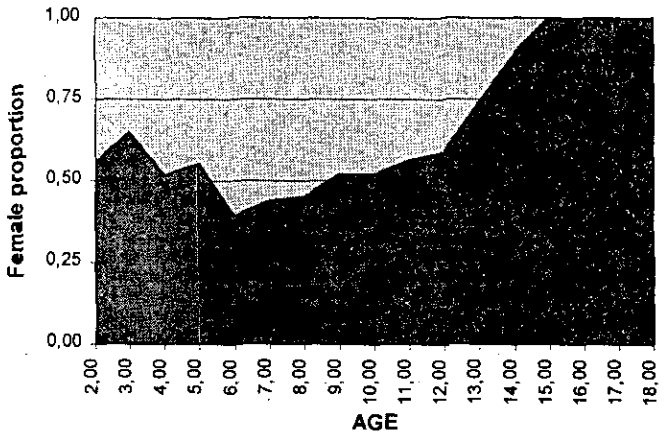


Figure 4. Female ratio by age, Flemish Cap 1993-1997.

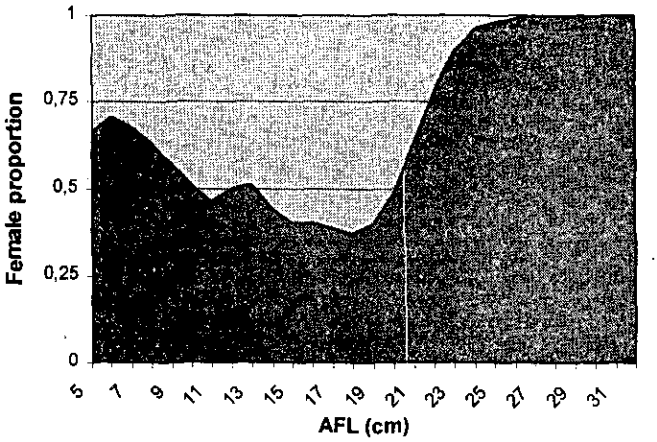


Figure 5. Female ratio by length, Flemish Cap 1993-1997

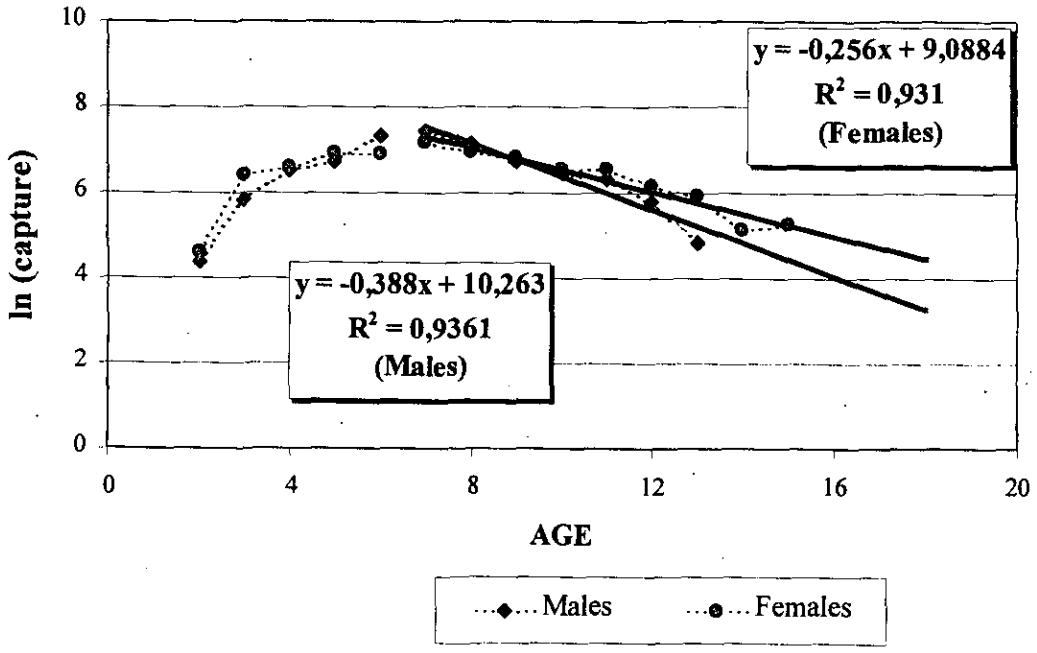


Figure 6. Catch curves for roughhead grenadier, females and males.