NOT TO BE CITED WITHOUT PRIOR
REFERENCE TO THE AUTHOR(S)

Northwest Atlantic Fisheries Organization

Serial No. N4454 NAFO SCR Doc. 01/75

SCIENTIFIC COUNCIL MEETING – JUNE 2001

Monitoring Update of the Roughhead Grenadier Stock Assessment in NAFO Subareas 2 and 3

by

S. Junquera[1] H. Murua [2] and K. Patterson [3]

[1] IEO – Instituto Español de Oceanografía, Vigo, Spain
[2]AZTI – Technological Institute for Food and Fish, San Sebastian, Spain
[3] DG FISH, European Commission, Brussels, Belgium

Abstract

The revised catch history after 1987 is presented, total SA 2+3 roughhead grenadier catch in 2000 was 4767 tons. The trends in biomass estimates from four survey series are examined: Canadian fall, Canadian spring, Spanish spring 3NO and EU summer 3M. Only the Canadian fall surveys are considered to cover adequately the species distribution range. The biomass index from this survey in 2000 was 29139 t , 36 % of it in Div. 3L.

Commercial catch include mainly ages between 5 and 10, with a peak at age 6. An age structured production model has been performed as a trial. The result of it indicate a moderate decrease in the total biomass but a sharp decrease in SSB. The F reference obtained is 0.41. The C/ B index using data from the Canadian fall survey is 0.16 (C/B_{1999} = 0.27).

Commercial catches

The revised catch history after 1987 is presented in Table 1 and Figure 1. Catches increased gradually until 1999 (7160 tons) and in 2000 decrease to 4767. At present most catches are taken en Div. 3LMN and no catches are recorded in SA 2. The largest proportion of those catches by country corresponds to Spain (3948 t), as Portuguese catches sharply decreased in this last year (Table2).

Research Survey Data

- **Canadian fall survey**

Stratified random bottom trawl surveys have been conducted in Div. 2GHJ and 3KL in fall since 1978, usually in October-November. Since 1990 the survey also covered Div. 3NO. Until 1995 an Engel trawl was used, changed since then to a Campelen 1800. Surveys depth is up to 1500m in Div. 2GHJ and 3K and to 730 m in Div. 3LNO, extended to 1463 m after 1995. A description of those surveys is in McCallum and Walsh (1996) and Power and Parsons (1998). In 2000 a total of 26 hauls have been made in Div. 3M at depths between 730 – 1460 m.

The roughhead biomass indexes from this series of surveys are presented in Table 3 and Fig. 2. The aggregated biomass estimates in 1978 was 24048 t., increased to a peak in 1998 (41148 t) and is decreasing since then to 29139 t in 2000. However the estimates from 1995 onwards are not directly comparable with the previous time series because of the change in the survey gear. According to the biomass estimates from this series of surveys (Table 3), the main part of the stock used to be distributed mainly in Div. 3K, followed by Divisions 2J and 3L. Since 1984 the proportion of the total survey biomass in 3L is increasing, as it does also in Div. 3N since 1993. In

2000 this proportion was 36 %, while this proportion in 2J and 3K maintain the decreasing trend. The sharp increase observed in 3M in this last year can be explained by a better coverage of the survey in that area compared with previous years.

- **Canadian spring survey**

Stratified random bottom trawl surveys have been conducted in Div. 3L and 3N in spring since 1978. A description of those surveys is found in McCallum and Walsh (1996). Until 1996 an Engel trawl was used, changed to a Campelen 1800 since then. In 2000 the survey covered up to 730 metres depth, and thus the roughhead distribution range was only partially covered.

The roughhead biomass obtained in this series of surveys are presented in Table 4 and Figure 2. The biomass estimate in 2000 was the largest of the series (5006 t). However again in this case a direct comparison of the biomass levels through the whole time series is not possible due to the change in the survey gear in 1995. Biomass was still largely concentrated in Div. 3L, though an increase is observed in the biomass proportion found in 3N and a small part was for the first time reported in 3O. Biomass estimates from the spring survey series are considerably lower than the ones obtained in the fall series, as the surveys cover only the southern divisions and the shallower depths.

- **Canadian deepwater survey**

Canada conducted deepwater bottom trawl surveys (750 – 1500 m.) in 1991, 1994 and in 1995 in Divisions 3 KLMN. The 1991 survey was carried out in August, the 1994 in February and the 1995 in spring. The results of those surveys were reported by Atkinson et al. (1994) and Bowering et al. (1995), and are presented in Table 5 and Figure 2. It is observed an increasing trend from 16215 t. in 1991 to 46668 in 1995. Most part of the biomass was taken in Div. 3L and 3M, which confirms that the stock in those Divisions are distributed beyond the depths covered by the spring surveys in those Divisions. The increased estimates for Div. 3L and 3M in 1994 were probably due, at least in part, to the increased survey area (Atkinson *et al.*, 1994). The results suggest somewhat higher biomass in southern 3L and 3N.

- **Spanish spring survey.**

Since 1995, a stratified bottom trawl survey is conducted in April – May in Div. 3NO Regulatory Area (Paz *et al.* 1995, 1996 and 1997; Durán *et al.* 1998). The depth range of this survey was progressively increased every year, as indicated in Table 6, to a maximum depth of 1463 since 1998. A parallel increase in the biomass estimates was observed in the survey series (Table 6 and Fig. 2), very pronounced in 1998 where 50843 t. Biomass index obtained in 2000 was 41111 t, most part of it beyond 1000 m and mainly concentrated at depths 1281 – 1463 m.

- **EU (Spain and Portugal) summer survey**

EU- Spain and Portugal conduct a stratified bottom trawl survey in Div. 3M since 1988, up to depths of 730. The survey procedure is described in Vázquez (2000). The roughhead grenadier biomass indices from this survey series, updated from Murua (2001), are presented in Table 7 and Fig. 2. A peak biomass of 3595 was observed in 1993, apart of this, the biomass estimates from this survey are rather stable at about the same level than last year. Roughhead significant biomass only is found at depths beyond 500 m every year.

Biological Data

Roughhead length frequencies from the Spanish, Portuguese and Russian trawl catches in Div. 3LMNO are available from Junquera *et al.* (2001), Vargas *et al.* (2001) and Vaskov *et al.* (2001) respectively. The Spanish and Portuguese lengths frequencies are preanal fin lengths, while the Russian ones are total lengths. The trends in the mean lengths from the Portuguese and Spanish catches since 1995 are presented in Fig. 3. Mean lengths are higher every year in the Spanish catches. In both series a decline in this value is observed, from 18.5 to 16.5 cm in the Spanish series and from 15.5 to 12 cm in the Portuguese one.

Murua (2001) presents a review on the roughhead population structure on Flemish Cap (Div. 3M) based on the UE summer survey series. Age and length composition of the catches show differences by sexes. The males proportion declines with length. The largest male caught in the surveys was 24 cm (PFL) and larger lengths are all from females. Also the mean females length in the catches was larger than the males one (16.7 and 15.4 cm respectively). As length composition of the catches increases with depth, females ratio increases in the same way. Though the results presented in this paper are based on a survey that only covers the shallower part of the roughhead distribution (up to 730 m depth), they are in agreement with the results presented by Savvatimsky and Gorchinsky (2001) based on the fishery.

Catch at age data of the Spanish, Portuguese and Russian commercial catches are presented in Table 8. Those were obtained using data from Junquera *et al.* (2001), Vargas *et al.* (2001) and Vascov *et al.* (2001). The roughhead length composition from the Russian catches haven been transformed into PFL using the relationship “total length / PFL” obtained by Murua and Motos (1997). Total catches are composed mainly by ages between 5 and 10 with a peak in age 6 in 2000, without differences between countries.

According to Murua (2001), the females proportion at age is between 40 – 50 % for ages up to 12 (mean PFL 20 cm), increasing thereafter. At age 14 female ratio is 80 % (mean PFL 24 cm). Females are 100 % of the catch after that age. Similar results on sex ratios at age are also reported by Savvatimsky (1994) and Savvatimsky and Gorchinsky (2001). To explain the differences in sex ratios at age, two reasons are pointed by Murua (2001): differences in growth rate by sex and differences in mortality by sex. Differences in growth rate by sex, that are reflected in different mean lengths at age, have been already documented (Savvatimsky 1994; Jorgensen 1996; Rodriguez-Marín et al. 1998).

Also differences in natural mortality can be considered, since males disappear from the catches at the larger lengths. Murua (2001) presents a catch curve by sexes, fitted by pooling data on roughhead catches at age in the EU summer survey from 1994 to 2000. According to it, both sexes would be fully recruited at age 8. Clear differences in total mortality between sexes are found, 0.29 in females and 0.59 in males respectively, though it must be noted that those estimates are based on survey data from an area much shallower than the one where the fishery is performed.

Application of an Age-structured Production Model

In 2000 the available information was assembled in the framework of an age-structured production model for exploratory purposes (Murua et al 2000). In this paper it has been updated using data on fisheries and surveys from 2000. An age structured production model can be considered, very approximately, as a combination of a classic catch-curve analysis and a biomass-dynamic surplus production model. The stock dynamics are modelled by the equations:

$$N_{y+1,a} = \begin{cases} N_{y+1,0} & (a=0) \\ N_{y,a-1} * e^{-(M+S_{a-1})*F_y} & (all \quad other \quad ages) \end{cases}$$

where $N_{y\,a}$ is the number of fish at age a in year y
M is the natural mortality
$N_{y,\,0}$ is the number of age 0 in year y (recruitment)
S_a is the age selectivity
F_y is the reference fishing mortality in year y

The recruitment is considered to be functionally related to spawner stock size by Beverton-Holt stock-recruitment relationship:

$$N_{y,0} = \frac{a * SSB_{Y-1}}{b + SSB_{Y-1}}$$

$$SSB_{y-1} = \sum_a f_a * N_{y-1,a} * W_{y-1,a}$$

where

f_a is the maturity ogive value at age a

$W_{y-1,a}$ is the weight at age in the year y-1

The predicted catches in weight for every year are obtained by applying the conventional catch equation, and then

$$\hat{C} = Fy * \hat{B} = q * fy * \hat{B}$$

where: q is the catchability

$\hat{B}$ is the predicted fishable biomass

The data used in the model are :

- Commercial catches at age in 1997 to 2000, $C_{a,y}$.
- Commercial catches in weight from 1987 to 2000, A_y.
- Estimates of abundance $U_{s,y}$ in EU 3M surveys and Canadian surveys (data in 1995 and later are treated as a separate survey on account of a gear change).
- Estimates of partial recruitment S_a ,maturity O_a and weights at age W_a from Table 9.

The following modelling assumptions are made:

- Catches are known with much higher precision than that of other sources of information
- Survey estimates of biomass exhibit a simple proportionality to exploitable biomass in the stock, ie $U_{s,y}=q_s B_y$.
- The variances of the two surveys are assumed to be equal.
- Fish are assumed fully recruited at ages 10 and above.

The parameters estimated are :

- Fishing mortality by year, F_y , referenced to fully-recruited ages.
- Parameters a and b of the stock-recruit relationship
- Catchabilities in the surveys, q_s
- Variance of the surveys, σ^2_s
- Variance of the catch-at-age observations, σ^2_c
- Natural mortality, M.

The model is fitted by a nonlinear minimisation of :

$$\sum_{a=10}^{a=18}\sum_{1997}^{2000}\frac{1}{\sigma_c^2} * \ln\left(\hat{C}_{a,y} / C_{a,y}\right)^2 + \sum_{1995}^{2000}\frac{1}{\sigma_s^2}\ln\left(\hat{U}_{1,y} / U_{1,y}\right)^2 + \sum_{1987}^{2000}\frac{1}{\sigma_s^2}\ln\left(\hat{U}_{2,y} / U_{2,y}\right)^2 + \sum_{1989}^{2000}\frac{1}{\sigma_s^2}\ln\left(\hat{U}_{3,y} / U_{3,y}\right)^2 + \sum_{1987}^{2000}\frac{1}{\sigma_A^2}\ln\left(\hat{A}_y / A\right)^2$$

Where σ_c^2 and σ_s^2 are calculated in successive iterations but σ_A^2 is arbitrarily set = 0.02. Here $\hat{U}_1$ represents Canada Fall survey (Campelen gear), $\hat{U}_2$ represents Canadian Fall survey, and $\hat{U}_3$ represents EU Flemish Cap survey data. Expected values are calculated as

$$U_{s,y} = q_s \sum_a S_a N_{a,y} W_a$$

and

$$A_y = \sum_a C_{a,y} W_{a,y}$$

The variances were estimated iteratively. An arbitrary inverse variance weight of 50 constrains the model estimates of catches to the reported catches.

Results are shown in Figure 4 and parameter estimates are given in Table 10. The corresponding estimate of natural mortality was 0.28 and the reference F for the fully recruited ages is 0.41. The model indicates a moderate decline in exploitable biomass, but the SSB estimated as having undergone a much sharper decline, to about one-quarter of its value in the late 1980s. This difference in trend is due to the very late age of first spawning for this species. The reference F shows a continuous increasing trend.

Assessment

The Canadian fall survey series is the best input for the assessment of this stock, because it provides a synoptic view of the species distribution over a wide geographic and depth range, in spite the objections that has been pointed to this series, regarding the changing depth coverage and the change of the survey gear (Anon. 1998). In 2000 most of the biomass concentrate in Div. 3L, at depths between 1000-1200 m. Regarding the depth distribution of the surveys biomass estimates, it must be noted that it is truncated at the depths where the highest biomass are found in all the surveys series considered. It could indicate that a significant part of the stock biomass would distribute beyond the surveyed depths.

According to the fall Canadian surveys and the Spain 3NO surveys (Fig. 2), the ones with a wider depth range, the roughhead total biomass indices would indicate a general increasing trend. This is also observed in the Canadian spring survey, while in the summer EU survey the 2000 index slightly decreases, however both survey series only cover the shallowest part of the roughhead range. The catch / biomass (C/B) index obtained with the Canadian fall survey (Fig. 5) is 0.16 which is slightly lower than that of this last year (C/B_{1999} = 0.27). The trend observed in the C/B index is similar to the observed in the Greenland halibut stock (Cárdenas et al. 1999), due to the close association of this two species in the catches.

The yield per recruit analysis performed in previous years (Junquera et al. 1999 and Murua et al. 2000) gave similar results, with estimates of $F_{0.1}$= 0.129 and F_{max} = 0.261. Considering the reference F obtained from the age structured production model performed (F = 0.41), this stock would be exploited at a level well above F_{max}. This fact in addition of the very late age at maturity would account for the large decrease in the SSB through the period analysed. On the other hand, accepting the C/B as an index of the reference F, the stock would exploited at levels between $F_{0.1}$ and F_{max}. It must be noted that only 2 % of the catch at age in numbers and 12 % in weight is above the female length at maturity (15 years).

References

Anon. (1998).- NAFO Scientific Council Report 1998.

ATKINSON, D. B., D. POWER and J. MORGAN (1994).- Roundnose grenadier (*Coryphaenoides rupestris*) and Roughhead grenadier (*Macrourus berglax*) in NAFO Subareas 2+3. *NAFO SCR Doc.* 94/**48**.

BOWERING, W. R., D. POWER and M. J. MORGAN (1995).- Distribution and abundance of five major groundfish species at the continental slope of Divisions 3KLMN based upon Canadian deepwater surveys in 1991, 1994 and 1995. *NAFO SCR Doc*. 95/**51**.

DE CÁRDENAS, E., A. AVILA DE MELO, S. IGLESIAS and F. SABORIDO (1995).- Selectivity of 130 mm mesh size in deep sea bottom trawl fishery in NAFO Regulatory Area. *NAFO SCR Doc.* 95/**47**.

DE CÁRDENAS, E., L. MOTOS and S. JUNQUERA (1999).- A simple method to project catches in the absence of VPA. *NAFO SCR Doc*. 99/**2**.

DURÁN, P.; X. PAZ and E. DE CÁRDENAS (1998).- Results from the 98 Spanish bottom trawl survey in the NAFO Regulatory area for 3NO. *NAFO SCR Doc*. 98/**48**.

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

JUNQUERA, S., H. MURUA and E. CARDENAS (1999).- An assessment for roughhead grenadier (*Macrourus berglax*) in NAFO Subareas 2 and 3. *NAFO SCR Doc*. 99/**64**.

JUNQUERA, S., A. VÁZQUEZ, H. MURUA, E. ROMÁN and J. L. DEL RÍO (2000).- Spanish Research Report for 1999. *NAFO SCS Doc*. 00/**20**.

JUNQUERA, S., A. VAZQUEZ, H. MURUA, J.L. DEL RIO, E. ROMAN and F. GONZALEZ (2001).- Spanish research report for 2000. NAFO SCS Doc. 01/**18**.

MCCALLUM, B. R. and S. J. WALSH (1996).- Groundfish survey trawls used at the Northwest Atlantic Fisheries Centre, 1971-present. *NAFO SCR Doc*. 96/**50**.

MURUA, H. and L. MOTOS (1997).- Length at first maturity of roughhead grenadier *Macrourus berglax* in NAFO Div. 3LMN. NAFO SCR Doc. 97/**19**.

MURUA , H. (2000).- A review on roughhead grenadier (*Macrourus berglax*) biology and population structure on Flemish Cap (NAFO Div. 3M) 1991-1999. *NAFO SCR Doc.* 00/**30**. 19pp.

MURUA, H. (2001).- A review on roughhead grenadier (*Macrourus berglax*) and population structure on Flemish Cap (NAFO Division 3M), 1991 – 2000. *NAFO SCR Doc*. 01/**29**.

MURUA, H, S. JUNQUERA and K. PATTERSON (2000).- Assessment of roughhead grenadier, *Macrourus berglax*, in NAFO Subareas 2 and 3. *NAFO SCR Doc.* 00/**39**.

PAZ, X.; J. MARTINEZ and E. DE CÁRDENAS (1995).- Preliminary results from the 95 Spanish bottom trawl survey in the NAFO Regulatory area for 3NO. *NAFO SCR Doc*. 95/**55**.

PAZ, X. ; P. DURÁN and E. DE CÁRDENAS (1996).- Preliminary results from the 96 Spanish bottom trawl survey in the NAFO Regulatory area for 3NO. *NAFO SCR Doc*. 96/**49**.

PAZ, X. ; P. DURÁN and E. DE CÁRDENAS (1997).- Preliminary results from the 97 Spanish bottom trawl survey in the NAFO Regulatory area for 3NO. *NAFO SCR Doc*. 97/**25**.

POWER, D., and D. MADDOCK PARSONS (1998).- An assessment of roundnose grenadier (*Coryphaenoides rupestris*) in NAFO Subareas 2+3 and catch information on Roughhead grenadier (*Macrourus berglax*). *NAFO SCR Doc*. 98/**57**.

RODRIGUEZ-MARIN, E., M. RUIZ and A. SARASUA (1998).- Validation of roughhead grenadier (*Macrourus berglax*) otolith reading. *NAFO SCR Doc.* 98/**33**.

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

SAVVATIMSKY, P.I. and GORCHINSKY, K. V. 2001. By-catch of Grenadiers in Directed Fishery for Greenland Halibut in Divisions 3LMN and Size, Age and Sex Composition of Roughhead Grenadier 2000. *NAFO SCR Doc.* **01/9.** Serial No. N4375.

VARGAS, J.; R. ALPOIM, E. SANTOS and A. M. AVILA DE MELO (2001).- Portuguese Research Report for 2000. *NAFO SCS Doc*. 00/**9**.

VASKOV, A. A., T. M. IGASHOV and V. M. KISELEVA (2000).- Russian Research Report for 1999. *NAFO SCS Doc.* 00/**9** PART II.

VASKOV, A. A., K.V. GORCHINSKY, T. M. IGASHOV, V. M. KISELEVA and S.P. MELNIKOV (2001).- Russian Research Report for 2000. *NAFO SCS Doc.* 01/**11** PART II.

VÁZQUEZ, A. (2000).- Results from the bottom trawl survey of Flemish Cap in July 1999. *NAFO SCR Doc.* 00/9.

Table 1.- Revised grenadier nominal catches (t), updated from Murua et al. (2000).

Year	2G	2H	2J	3K	3L	3M	3N	3O	Other	TOTAL
1987					912	7	82			1001
1988		1			907		52			960
1989		2		3	289	28	11			333
1990		1	32		2211	688	312			3244
1991[a]			12	113	2543	497	1093	10		4268
1992			23	274	2582	2961	760	125		6725
1993			10	193	996	1428	1680	61	27	4395
1994[b]	1		2	35	585	2301	1062	28	9	4023
1995[b]	22	6	16	16	1199	1625	1074	20	4	3982
1996[b]					1945	888	1300	2		4135
1997[b]	36	5	63	100	1774	922	1797	43		4740
1998[b]					2652	2180	2289	18	92[c]	7139
1999[b]				61	2037	3127	1705	180	49[c]	7160
2000[b]				139	2485[d]	4160[d]	1666[d]	543[d]	211[c]	4767

[a] Catch could not be well estimated; based on revised data is estimated to be 8000 to 14000 t.mixed roundnose and rouhhead grenadiers. (Power and Parson 1988).
[b] Provisional.
[c] Russian catches reported for Divisions 3LMNO together. From Vaskov et al. (2000) and Vaskov et al. (2001).
[d] Includes a portion of catches reported by observers.

Table 2.- Roughhead grenadier nominal catches (t.) in Subarea 2+3, updated from Murua et al. (2000), Vargas et al. (2001) and Vaskov et al. (2001).

	1987	1988	1989	1990	1991	1992	1993	1994[a]	1995[a]	1996[a]	1997[a]	1998[a]	1999[a]	2000[a]
Canada				31	215	595	345	79	84		240		108	210
Estonia														1
Former GDR		49	43											
EU-ESP						4125[b]	2054[b]	1720[b]	2521[b]	3090[b]	3738	6050	5704	3948[d]
EU-PRT	1001[b]	914[b]	290[b]	3211[b]	4486[b]	2000[b]	1969[b]	2223[b]	1402[b]	784[b]	762	1089	1299	396
Norway				2										
Lituania														1
Russia												92[c]	49	211
TOTAL	1001	963	333	3244	4701	6720	4368	4022	4007	4131	4740	7231	7160	4767

[a] Provisional.
[b] First reported as roundnose grenadier
[c] Reported as roundnose grenadier in STATLANT 21A.
[d] Reported by observers

Table 3.- Roughhead biomass indices from the fall Canadian survey series and percentages of the biomass indices by Division.

		Percentages of biomass (%)							
Year	Biomass (t)	2G	2H	2J	3K	3L	3M	3N	3O
1978	24048			31	46	24			
1979	15962			37	63				
1980	17229			49	51				
1981	19451			29	43	28			
1982	22762			33	36	31			
1983	16597			38	49	13			
1984	26301			22	28	50			
1985	15661			14	31	55			
1986	6733			61	39				
1987	20763			14	15	71			
1988	9734			28	24	48			
1989	6433			34	14	52			
1990	12455			24	30	46			
1991	8900			16	36	47		2	
1992	2848			44	14	41			
1993	2779			20	30	31		16	3
1994	1915			23	23	37		14	3
1995	6933			8	44	25		21	2
1996	32954		2	8	14	53	21	1	
1997	32313	6	3	9	17	39	21	5	
1998	41148	1	2	9	15	39	13	20	1
1999	31328	2	3	11	17	50	12	6	1
2000	29139	0	0	10	10	36	14	17	2

Table 4.- Roughhead biomass indexes (tons) from the Canadian spring survey series and percentages of biomass in the Divisions surveyed. ns = not surveyed.

		Percentages of biomass (%)		
Year	**Biomass (t.)**	**3L**	**3N**	**3O**
1978	2754	38	62	
1979	2105	93	7	
1980	4070	89	11	
1981	3115	91	9	
1982	608	84	16	
1983	ns	ns	ns	
1984	50	ns	100	
1985	2432	97	3	
1986	1096	98	2	
1987	2080	88	12	
1988	805	98	2	
1989	1439	99	1	
1990	475	98	2	
1991	264	95	5	
1992	1129	98	2	
1993	539	84	16	
1994	952	93	7	
1995	347	93	7	
1996	2854	97	3	
1997	3125	88	12	
1998	4919	86	14	
1999	4042	82	18	
2000	5006	71	25	4

Table 5.- Roughhead grenadier biomass index (tons) from the deepwater Canadian surveys and percentages of biomass by Divisions (from Bowering et al., 1995)

		Percentage of biomass (%)			
Year	**Biomass (t.)**	**3K**	**3L**	**3M**	**3N**
1991	16215	26	39	34	
1994	26588	16	34	39	11
1995	46668	15	48	25	13

Table 6.- Roughhead grenadier biomass indexes (t.) from the Spanish spring surveys in Div. 3NO. (ns – not surveyed depth).

	Year					
Depth (m)	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
55 – 92	0	0	0	0	0	0
93 – 184	0	12	0	0	0	0
185 – 274	0	0	0	0	0	0
275 – 366	12	0	35	11	0	0
367 – 549	0	45	42	64	0	0
550 – 731	363	213	73	701	99	0
732 – 914	*ns*	630	1504	1924	843	42
915 – 1097	*ns*	3943	5079	8399	3148	52
1098 – 1280	*ns*	*ns*	12882	23243	7093	2468
1281 – 1463	*ns*	*ns*	*ns*	16502	14405	38549
Total	**374**	**4842**	**19615**	**50843**	**25589**	**41111**

Table 7.- Rouhhead grenadier biomass indices (t.), and biomass per depth intervals from the EU summer survey in Div. 3M (from Murua 2001).

	Depth intervals (m.)			
Depth (m):	**266 - 380**	**381 - 570**	**571 - 760**	**Total**
1989	17	364	642	1024
1990		241	755	996
1991	7	327	1254	1587
1992	33	417	1426	1878
1993	25	895	2675	3595
1994		288	2058	2350
1995	35	533	1286	1855
1996	228	482	910	1619
1997	26	359	1039	1424
1998	48	510	1454	2012
1999	86	583	818	1487
2000	128	401	720	1246

Table 8.- Roughhead grenadier catch at age by country in Div. 3LMNO in 2000.

AGE	SPAIN	PORTUGAL	RUSSIA	TOTAL
2	18902	48821	8670	76393
3	83085	291000	23669	397754
4	235336	370552	27487	633375
5	642046	404700	63501	1110247
6	1451160	462790	75953	1989903
7	1179724	150332	60738	1390794
8	1347356	80686	67152	1495194
9	1369950	44555	54162	1468666
10	768672	24130	27945	820747
11	329352	13376	13223	355951
12	257030	13483	15006	285518
13	137926	9520	8277	155723
14	116535	7149	9238	132923
15	77177	4043	6040	87260
16	42822	2038	3085	47945
17	20050	1047	1615	22712
18	19769	1145	2458	23371
19	24090	1119	2935	28144
20	12974	376	1786	15136
21	8290	80	1340	9710
22	6015	82	942	7040
23	2276		201	2477
24	1146		165	1311
Total	8151682	1931025	475589	10558295
Catch (t.)	3948	396	211	4555

Table 9.- Roughhead grenadier input parameters used in the age structured production model. Partial recruitment (PR) from Cárdenas et al. (1995); maturity ogive (MO) comes from Murua et al. (1997) and mean weights at age are the mean weights at age in the 2000 catch.

AGES	PR	Mean W (kg)	M	MO
2	0.22	0.083	0.2	0.000
3	0.30	0.104	0.2	0.000
4	0.36	0.148	0.2	0.000
5	0.41	0.202	0.2	0.000
6	0.58	0.254	0.2	0.000
7	0.69	0.332	0.2	0.000
8	0.81	0.399	0.2	0.001
9	0.87	0.518	0.2	0.002
10	0.93	0.610	0.2	0.004
11	0.96	0.750	0.2	0.009
12	0.98	0.867	0.2	0.025
13	0.99	1.070	0.2	0.048
14	1.00	1.354	0.2	0.106
15	1.00	1.620	0.2	0.602
16	1.00	1.909	0.2	0.948
17	1.00	2.138	0.2	0.981
18+	1.00	2.505	0.2	0.999

Table 10.- Parameters and variance estimates for an age structured model applied to roughhead catches and surveys.

Beverton Holt Stock-Recruit Relation					**M**									
a		75745,202			0,28									
b		1												
Fishing Mortality by Year														
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Fref	0,03	0,02	0,01	0,08	0,13	0,20	0,14	0,14	0,14	0,15	0,19	0,32	0,38	0,41
Catchabilities														
Canada Fall		0,145	0,400											
EU 3M Survey		0,048	0,048											
Campelen		0,897	0,795											
Residuals					**Weighting**		**Wted SSQ**	**n obs**	**Variance**	**Inverse variance**		**Mean**		
Canada Fall Survey SSQ			**3,827**	11,630	3,012		11,526	8	0,332	3,012		0,332		
Campelen SSQ			**2,614**	11,182	3,012		7,872	6	0,332	3,012				
EU Survey 3M SSQ			**2,192**	2,182	3,012		6,602	12	0,332	3,012				
Catches			**0,044**	0,035	50		2,182	12	0,004	50				
Age-structure, 2000			**2,985**	3,044	4,690		14,000	14	0,213	4,690				
Total Weighted SSQ to Minimise							**42,181**							

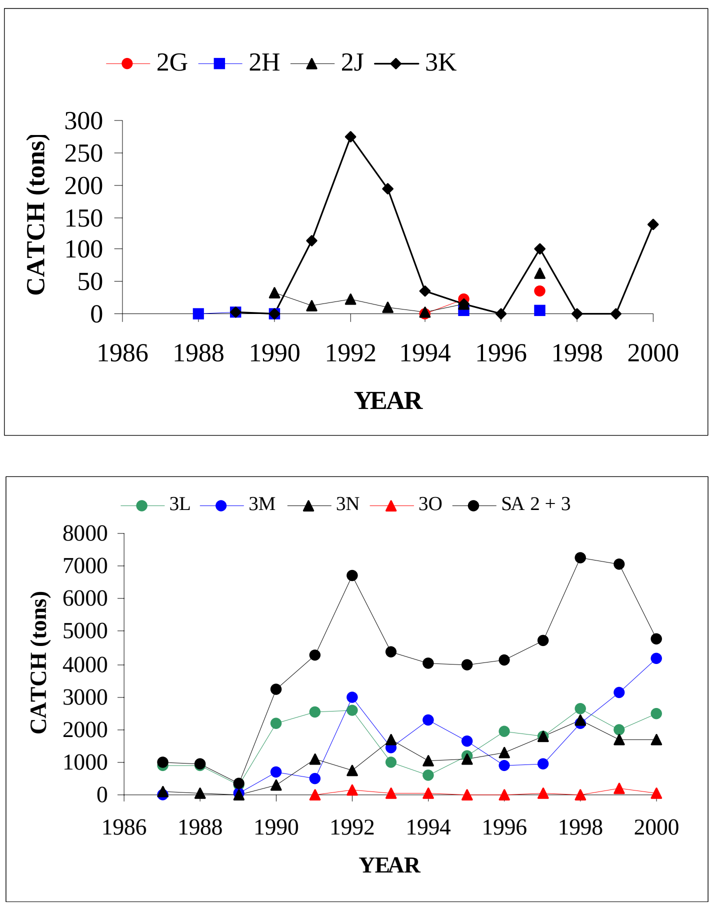

Figure 1.- Roughhead grenadier nominal catches by Division and the total for Subareas 2+3.

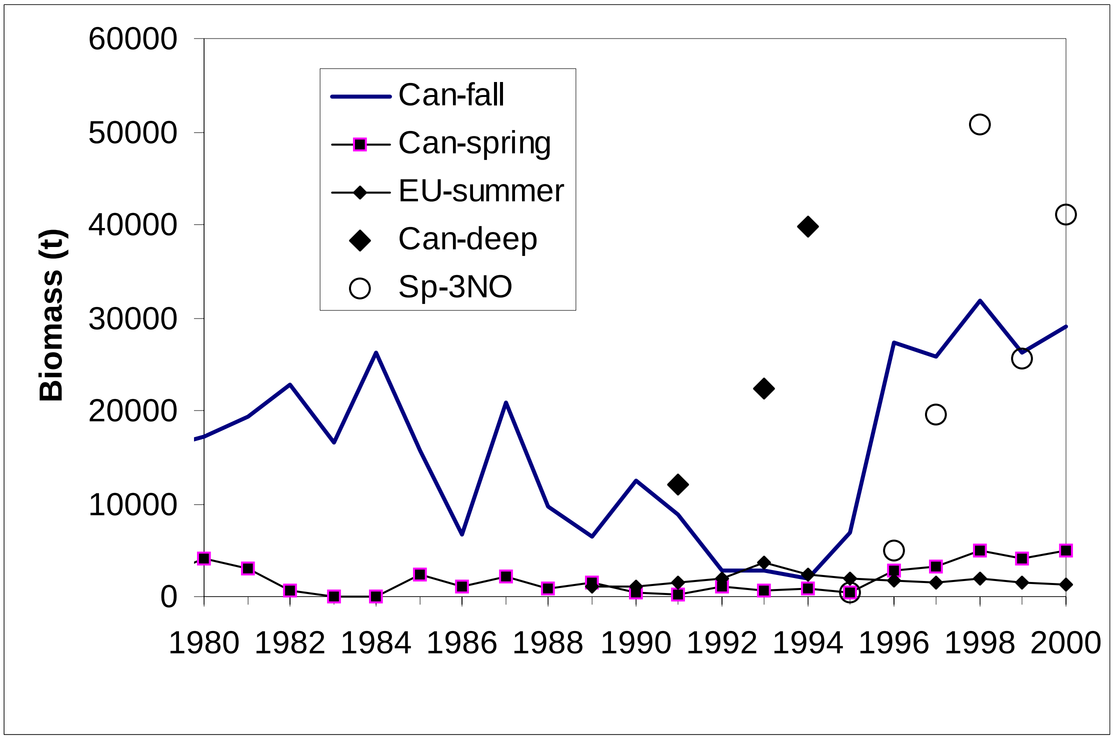

Figure 2.- Roughhead grenadier survey biomass indices from Subareas 2 + 3.

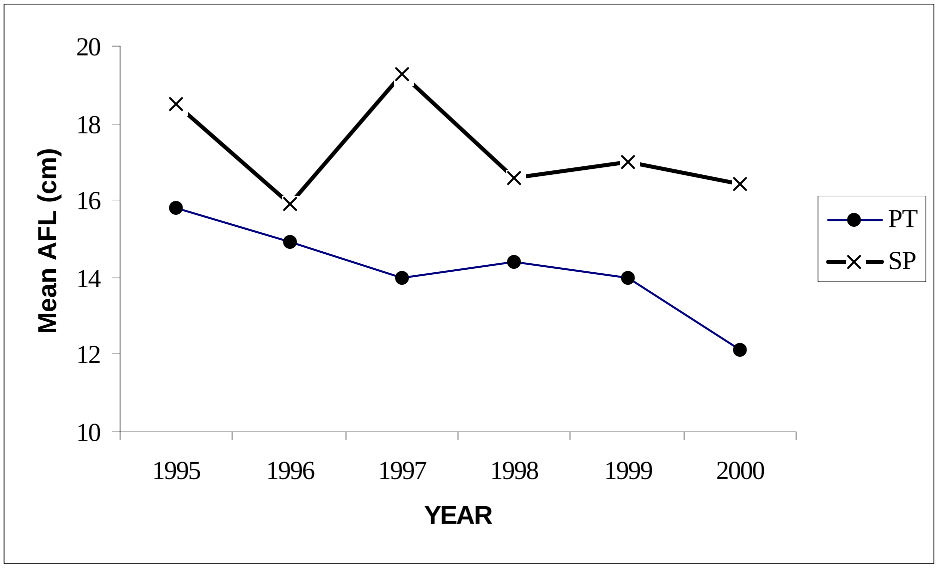

Figure 3.- Roughhead grenadier mean lengths (anal fin length) in the Spanish (SP) and Portuguese (PT) catches.

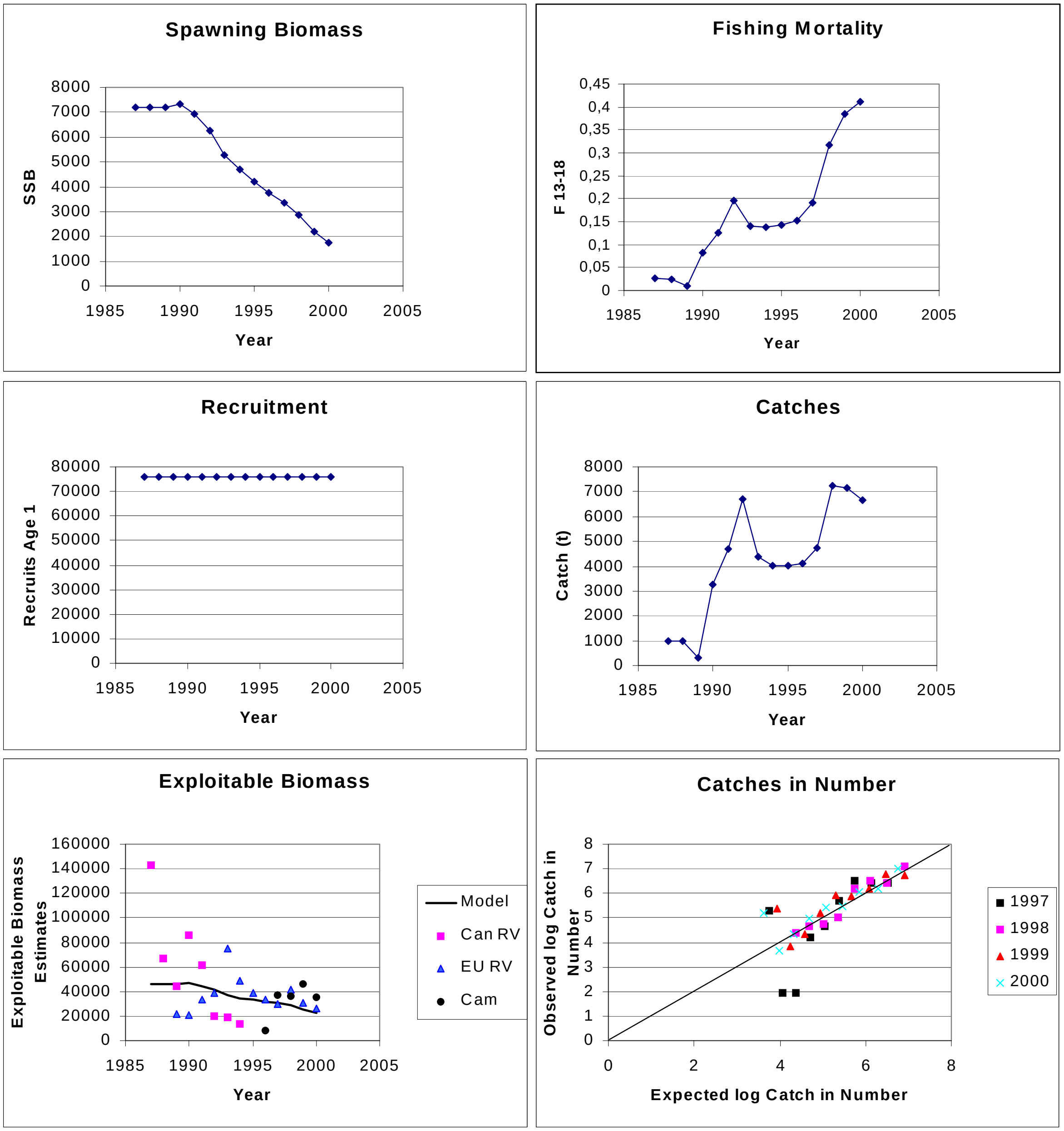

Figure 4. Summary of the results from age-structured production model applied to the roughhead catch and survey data .

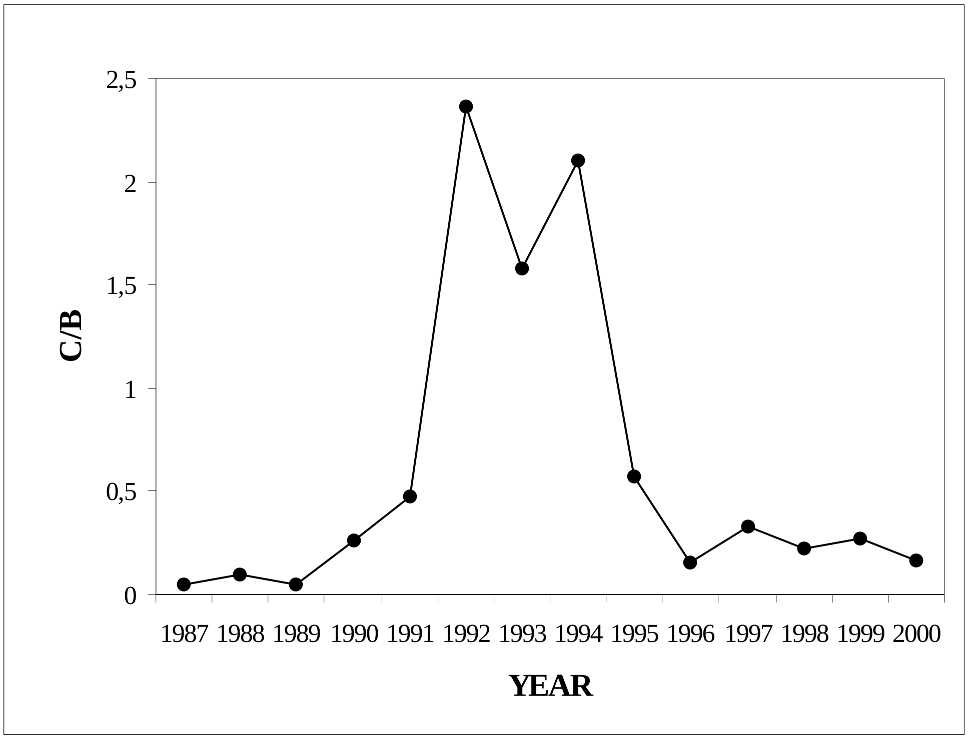

Figure 5.- Roughhead grenadier catch/biomass (C/B) index. Biomass index comes form the fall Canadian survey series.