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# Assessment of Roughhead Grenadier, *Macrourus berglax*, in NAFO Subareas 2 and 3

by

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## ABSTRACT

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 is mainly taken as by-catch in Greenland halibut fishery. Catches of roughhead grenadier increased sharply from 1989 (333 tones) to 1999 (7 200 tones). At the moment there is scarce information about the fishing pressure.

A yield per recruit analysis has been performed for males and females separately, and the estimated $F_{0.1}$ is 0.129 and $F_{max}$ is 0.261. Both values are in the same level as last year.

For exploratory purposes, available information was assembled in the framework of an age-structured production model. This can be considered, very approximately, as a combination of a classic catch-curve analysis and a biomass-dynamic surplus production model. The model indicates a moderate decline in exploitable biomass and much sharper decline in spawning biomass.

## COMMERCIAL CATCHES

It has been recognised that the recent catches of grenadiers by EU-Portugal and EU-Spain in Subarea 3, previously reported to NAFO as roundnose grenadiers, correspond to roughhead grenadier (Alpoim *et al.*, 1994; Power and Parsons 1998; Junquera 1998). The reason for this misclassification could be mainly because roundnose grenadier is the only name that appears in the statistical data reporting forms. The misreporting has not yet been resolved in the official statistics before 1996, but the species are reported correctly since 1997. Beginning in 1990, more roughhead grenadier has been caught than roundnose grenadier (Atkinson 1995). Roughhead grenadier is taken as by-catch in the Greenland halibut fishery in the Regulatory Area mainly in Divisions 3LMN.

It is uncertain the level of roughhead grenadier catches in Subareas 2 and 3 prior to the start of the deep-water Greenland halibut fishery in the Regulatory area, in 1988. Parsons (1975) indicate that in Northwest Atlantic only the roundnose grenadier has been subjected to exploitation since about 1967, while the roughhead grenadier was a much more disperse resource, occurring only in limited numbers in the commercial grenadier catches off Northeast Newfoundland and Labrador. However it can be noted that those results refer to depths above 730 m, a much shallower depth than where the fishery is being conducted at present (up to 1700, mostly between 900 and 1200 m). Savvatimsky (1983) reported that roughhead grenadier amounted to 66 % by number and 49 % by weight of the total grenadier catch taken by long-line in Newfoundland and Flemish Cap area in 1982 (depths 310 to 1000 m).

The revised catch history after 1987 is presented in Table 1 and Figure 1. Catches increased gradually until 1999 (7 160 tons). As in previous years, in 1999 the largest proportion of catches by country corresponds to Spain and Portugal (Table 2).

## 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 1999 a total of 11 hauls have been made in Div. 3M at depths between 900 – 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 26300 t. in 1984, and then decreased slowly to a minimum value of 1978 t. in 1994. After, increased again to 32954 t. in 1996, 32313 t. in 1997, 41148 t. in 1998 and in 1999 was 31328 t. 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 biomass in 3L is increasing, as it does also in Div. 3N since 1993. In 1999, 50 % of the total roughhead biomass surveyed was found in Div. 3L. Divs. 3K and 3L combined account for 67 % of this total. It can be noted that, as in previous years, the whole depth range of the species is not covered because the survey depths in Div. 3NO only goes to 730 m. Hence the biomass estimates for those Divisions would underestimate the stock size. Because, as has been observed in recent years (Junquera et al. 1999), the largest biomass indexes were obtained at depths between 1000 – 1200 m. in all areas.

- **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. The depth range of the surveys is up to 914 metres.

The roughhead biomass obtained in this series of surveys are presented in Table 4 and Figure 2. The biomass estimate slightly decreased to 3474 tons comparing with the highest level of 4919 in 1998. However, a general increasing trend in biomass is observed from 1995 onwards. But 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 is largely concentrated in Div. 3L. Biomass estimates from the spring survey series are considerably lower than the ones obtained in the fall series, as the first surveys cover only the southern divisions and the shallower depths, where according to the other results this species is less abundant.

- **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 in 1998 and 1999. 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. have been taken, though it decreased to 25589 t. in 1999. Biomass estimates largely concentrates at depths beyond 500 m. in every year.

- **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 indexes from this survey series, updated from Murua (2000), 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 about a mean of 1700 tons. 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.* (2000), Vargas *et al.* (2000) and Sigaev *et al.* (2000) respectively. The mean lengths (preanal fin lengths) from the commercial catches (Fig. 3) are stable from 1995 to 1999. In 1999 the proportion of both sexes in the commercial fishery was similar, though the female proportion was slightly higher in Div. 3M in the Spanish catches. Females attain larger sizes than do males, and from 24 cm (AFL) all the individuals are females (Fig. 4).

Catch at age data of the Spanish, Portuguese and Russian commercial catches are presented in Table 8, based in the Spanish age-length key used in Junquera *et al.* (2000), and in data from Vargas *et al.* (2000) and Sigaev *et al.* (2000). Most of the Spanish catches are from ages between 7 and 9, with a mode at age 8, the same as in the Russian catches, while the modal age in the Portuguese ones are age 6.

The total catch at age in 1999 (Table 8) has been used to obtain a synthetic catch curve (fig 5) and according to it, a total mortality of 0.41 was estimated. In previous studies Murua et al. (1999) and Murua (2000) suggested a difference in M between sexes. The proportion of sexes at length shown in Fig. 4 could also support this view, as males disappear from 20-24 AFL onwards, and there is no indication of an increase in F on males at previous lengths. In order to analyse this, an estimate of Z by sexes have been performed using the catch at age by sexes of the pair-trawl fleet (Fig. 6). The results indicate Z values of 0.5 and 0.9 for females and males respectively, both values higher than the ones obtained by Murua *et al.* (1999); although this was estimated based on the Flemish Cap survey which only covers the shallowest distribution of roughhead grenadier.

## 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 1999 most of the biomass concentrate in Div. 3L and 3K, at depths between 1000-1200 m.

According to all the survey series analysed, the roughhead total biomass indexes in the fall Canadian survey, Canadian spring survey and the summer EU survey were stable in 1999, while it decreased almost 50 % in the 3 NO spring Spanish survey. The catch / biomass (C/B) index obtained with the Canadian fall survey (Fig. 7) is at the same level as in 1998 ($C/B_{1999}$ = 0.27). The trend observed in the C/B index is similar to the observed in the Greenland halibut fishery (Cárdenas et al. 1999), due to close association of this two species.

The Z estimate from the 1999 pair-trawl catches is 0.5 for females and 0.9 for males. A yield per recruit has been performed using the input data presented in Table 7. The partial recruitment vector comes from Cárdenas *et al.* (1995), the maturity curve at age from Murua and Motos (1997) and the mean weight at age from the 1999 age-length key. The input value of M has been set for males and females separately, and it has been estimated as the difference between Z by sex and the C/B index. The results of the yield per recruit appears in Figure 8. The estimated $F_{0.1}$ is 0.129 and $F_{max}$ is 0.261 . The $F_{0.1}$ value is in the same level than last year ($F_{0.1}$ = 0.13).

No changes in the mean length (Figure 3), that could suggest an excessive fishing pressure, are observed on the catch since 1995. The available time series of catches at age is too short to analyse trends in the SSB, however it can be noted that in 1999 only about 18 % of the catch was above the female age at maturity (15 years). We have scarce information at the moment to assess an appropriate exploitation level.

**TRIAL APPLICATION OF AGE-STRUCTURED PRODUCTION MODEL**

For exploratory purposes, available information was assembled in the framework of an age-structured production model. This can be considered, very approximately, as a combination of a classic catch-curve analysis and a biomass-dynamic surplus production model. The data used in the model are:

- Commercial catches at age in 1997 to 1999, $C_{a,y}$ .
- Commercial catches in weight from 1987 to 1999, $A_y$.
- Estimates of abundance $U_{s,y}$ in EU surveys on 3M 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 $U_{s,y}=q_sB_y$.
- The variances of the two surveys are assumed to be equal.
- Recruitment $R_y$ is modelled as a Beverton-Holt function, parameterised as $R_y = a.SSB_y\text{-}1/b+SSB_{y-1}$
- Fish are assumed fully recruited at ages 10 and above.

The structural model represents recruitment processes with the Beverton-Holt model and represents mortality and fishing processes with the conventional Baranov equations. No attempt was made to model the male and female populations separately.

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, $\sigma^2_s$
- Variance of the catch-at-age observations, $\sigma^2_c$
- Natural Mortality, M.

The model is fitted by a nonlinear minimisation of :

$$\sum_{a=10}^{a=18}\sum_{y=1997}^{y=1999}\frac{1}{\sigma_c^2}*\ln\left(C_{a,y}/C_{a,y}\right)^2+\sum_{1995}^{1999}\frac{1}{\sigma_s^2}\ln\left(U_{1,y}/U_{1,y}\right)^2+\sum_{1987}^{1999}\frac{1}{\sigma_s^2}\ln\left(U_{2,y}/U_{2,y}\right)^2+\sum_{1989}^{1999}\frac{1}{\sigma_s^2}\ln\left(U_{3,y}/U_{3,y}\right)^2+\sum_{1987}^{1999}\frac{1}{\sigma_A^2}\ln\left(A_y/A\right)^2$$

Where $\sigma_c^2$ and $\sigma_s^2$ are calculated in successive iterations but $\sigma_A^2$ is arbitrarily set = 0.02. Here $U_1$ represents Canada Fall survey (Campelen gear), $U_2$ represents Canadian Fall survey, and $U_3$ 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 9 and parameter estimates are given in Table 10. The corresponding estimate of natural mortality was 0.28. The model indicates a moderate decline in exploitable biomass, to almost half its value in the late 1980s. However, spawning biomass is 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.

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**Table 1 .-** Revised grenadier catches, updated from Power and Parsons (1998).

| | STATLANT RHG Nominal catches (t) by Division | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **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 |

[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).

**Table 2 .-** Roughhead grenadier nominal catches (t.) in Subarea 2+3, updated from Power and Parsons (1998), Junquera et al. (1999), Vargas et al. (2000) and Vaskov et al. (2000).

| | **1987** | **1988** | **1989** | **1990** | **1991** | **1992** | **1993** | **1994[a]** | **1995[a]** | **1996[a]** | **1997[a]** | **1998[a]** | **1999[a]** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Canada** | | | | 31 | 215 | 595 | 345 | 79 | 84 | | 240 | | 108 |
| **Former GDR** | | 49 | 43 | | | | | | | | | | |
| **EU-ESP** | | | | | | 4125[b] | 2054[b] | 1720[b] | 2521[b] | 3090[b] | 3738 | 6050 | 5704 |
| **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 |
| **Norway** | | | | 2 | | | | | | | | | |
| **Russia** | | | | | | | | | | | | 92[c] | 49 |
| **TOTAL** | 1001 | 963 | 333 | 3244 | 4701 | 6720 | 4368 | 4022 | 4007 | 4131 | 4740 | 7231 | 7160 |

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

**Table 3.** Roughhead biomass indexes from the fall survey series and percentages of the biomass 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 |

**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** |
| **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** | 3474 | 82 | 18 |

**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.

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

**Table 7.** Rouhhead grenadier biomass indexes (t.), and biomass per depth intervals from the EU summer survey in Div. 3M.

| | Bimass indexes (t.) | | | |
|---|---|---|---|---|
| **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 |

**Table 8.** Spain, Portugal and Russia roughhead grenadier catch at age in Div. 3LMN in 1999.

| AGE | SPAIN | PORTUGAL | RUSSIA | TOTAL |
|---|---|---|---|---|
| **2** | 990 | 12689 | 135 | 13814 |
| **3** | 111774 | 398753 | 997 | 511524 |
| **4** | 239344 | 341654 | 2230 | 583228 |
| **5** | 570321 | 664409 | 8465 | 1243195 |
| **6** | 843300 | 1001474 | 12723 | 1857497 |
| **7** | 1129135 | 630613 | 12706 | 1772454 |
| **8** | 1695718 | 545569 | 13010 | 2254298 |
| **9** | 1154714 | 236255 | 5610 | 1396578 |
| **10** | 734701 | 94629 | 3227 | 832557 |
| **11** | 758477 | 107185 | 4545 | 870207 |
| **12** | 427749 | 57542 | 3041 | 488333 |
| **13** | 324031 | 36263 | 2213 | 362508 |
| **14** | 343573 | 29478 | 1673 | 374723 |
| **15** | 162762 | 16968 | 1183 | 180913 |
| **16** | 67182 | 6959 | 912 | 75053 |
| **17** | 42197 | 4985 | 456 | 47639 |
| **18** | 61356 | 2993 | 625 | 64974 |
| **19** | 42210 | 1255 | 473 | 43938 |
| **20** | 50872 | 467 | 389 | 51727 |
| **21** | 26420 | 178 | 237 | 26835 |
| **22** | 9439 | 261 | 169 | 9869 |
| **23** | 11010 | 391 | 68 | 11469 |
| **24** | 1105 | | 17 | 1122 |
| **25** | 2970 | | | 2970 |
| **26** | 759 | | | 759 |
| **Total** | 8812111 | 4190968 | 75105 | 13078184 |
| **Catch (t.)** | 5704,1 | 1299 | 49 | 7052,1 |

**Table 9.** Input parameters of the roughhead grenadier yield per recruit analysis.

| AGES | Partial R. | Mean W (Kg) | M males | M females | Mat. Og. |
|---|---|---|---|---|---|
| **2** | 0.22 | 0.047 | 0.6 | 0.2 | 0.000 |
| **3** | 0.30 | 0.099 | 0.6 | 0.2 | 0.000 |
| **4** | 0.36 | 0.138 | 0.6 | 0.2 | 0.000 |
| **5** | 0.41 | 0.172 | 0.6 | 0.2 | 0.000 |
| **6** | 0.58 | 0.228 | 0.6 | 0.2 | 0.000 |
| **7** | 0.69 | 0.314 | 0.6 | 0.2 | 0.000 |
| **8** | 0.81 | 0.387 | 0.6 | 0.2 | 0.001 |
| **9** | 0.87 | 0.473 | 0.6 | 0.2 | 0.002 |
| **10** | 0.93 | 0.592 | 0.6 | 0.2 | 0.004 |
| **11** | 0.96 | 0.678 | 0.6 | 0.2 | 0.009 |
| **12** | 0.98 | 0.814 | 0.6 | 0.2 | 0.025 |
| **13** | 0.99 | 1.006 | 0.6 | 0.2 | 0.048 |
| **14** | 1.00 | 1.193 | 0.6 | 0.2 | 0.106 |
| **15** | 1.00 | 1.557 | 0.6 | 0.2 | 0.602 |
| **16** | 1.00 | 1.749 | 0.6 | 0.2 | 0.948 |
| **17** | 1.00 | 1.907 | 0.6 | 0.2 | 0.981 |
| **18+** | 1.00 | 2.783 | 0.6 | 0.2 | 0.999 |

**Table 10. Parameter Estimates and Variance Estimates for Age-Structured Production Model**

| **Beverton Holt Stock-Recruit Relation** | | **M** |
|---|---|---|
| a | 75290.64 | 0.28 |
| b | 1 | |

**Fishing Mortality by Year**

| | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fref | 0.03 | 0.03 | 0.01 | 0.08 | 0.13 | 0.20 | 0.15 | 0.14 | 0.15 | 0.16 | 0.20 | 0.35 | 0.44 |

**Catchabilities**

| | |
|---|---|
| Canada Fall | 0.150005 |
| EU 3M Survey | 0.049251 |
| Campelen | 0.873657 |

| **Residuals** | | **Weighting** | **Wted SSQ** | **n obs** | **Variance** | **Inverse variance** | **Mean Surv. Var.** |
|---|---|---|---|---|---|---|---|
| Canada Fall Survey SSQ | **3.797432** | 2.940008 | 11.16447888 | 9 | 0.340109 | 2.940236 | 0.340109 |
| Campelen SSQ | **2.485827** | 2.940008 | 7.308351198 | 5 | 0.340109 | 2.940236 | |
| EU Survey 3M SSQ | **2.219461** | 2.940008 | 6.52523132 | 11 | 0.340109 | 2.940236 | |
| Catches | **0.037728** | 50 | 1.886412998 | 13 | 0.002902 | 50 | |
| Age-structure, 1999 | **2.514595** | 7.552088 | 18.99044723 | 19 | 0.132347 | 7.555887 | |
| **Total Weighted SSQ to Minimise** | | | **45.87492163** | | | | |

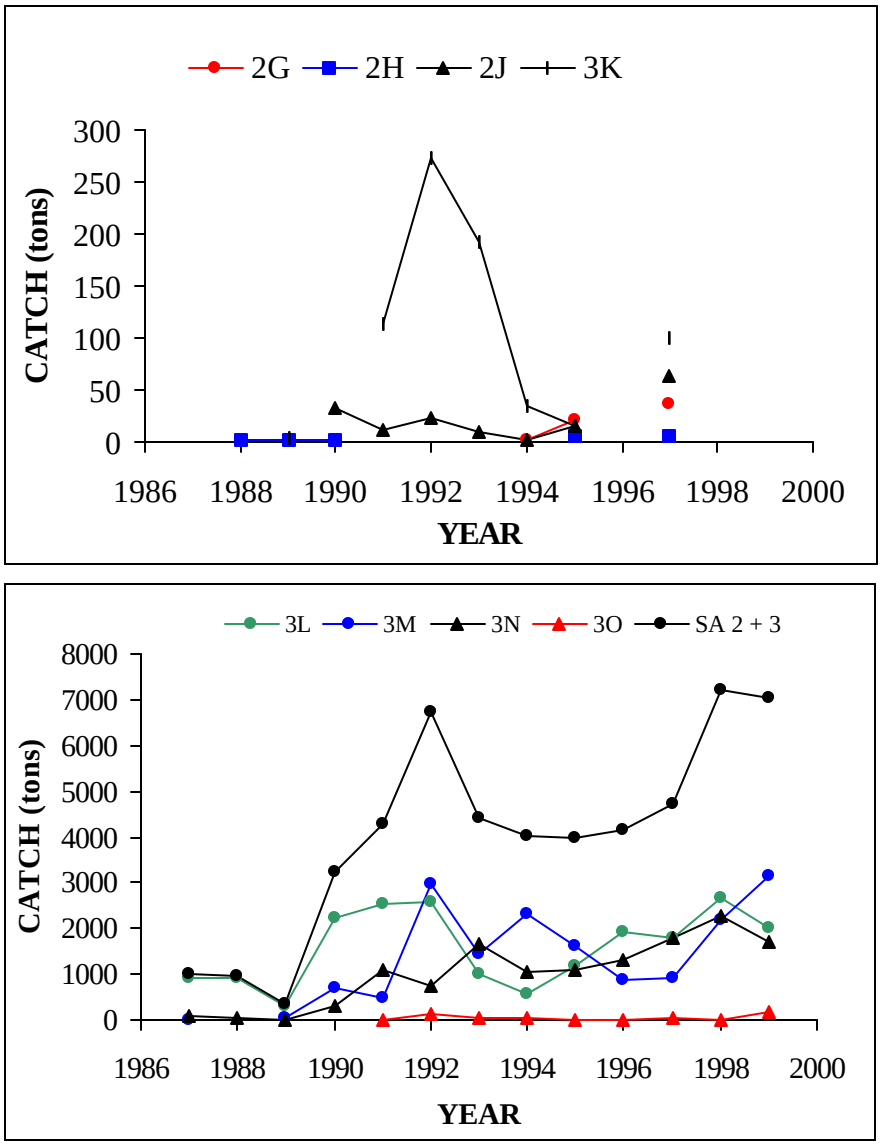


**Figure 1.-** Roughhead grenadier nominal catches by Division and the total for Subareas 2+3.

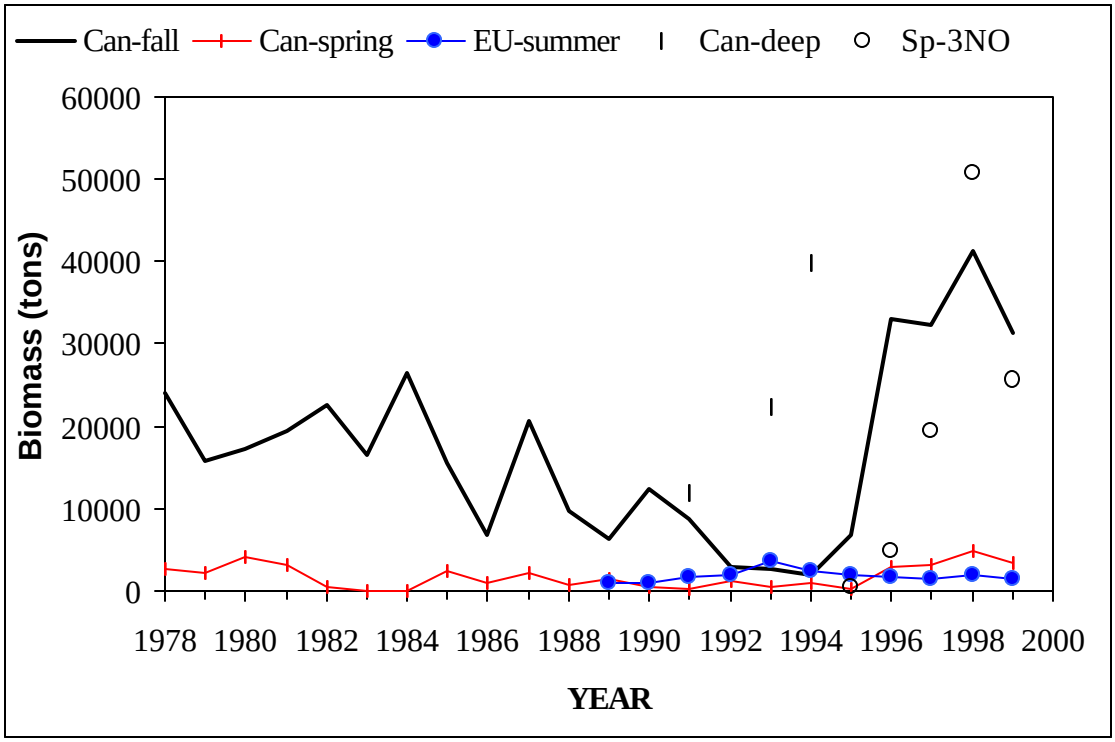


**Figure 2.-** Roughhead grenadier survey biomass indexes from Subareas 2 + 3.

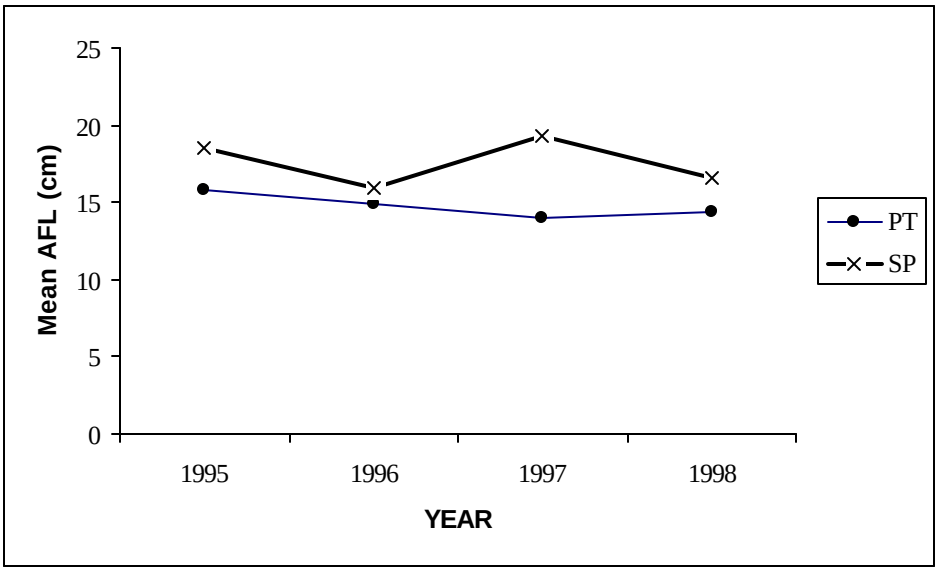


**Figure 3.-** Roughhead grenadier mean lengths (anal fin length) in the Spanish (SP) and Portuguese (PT) catches.

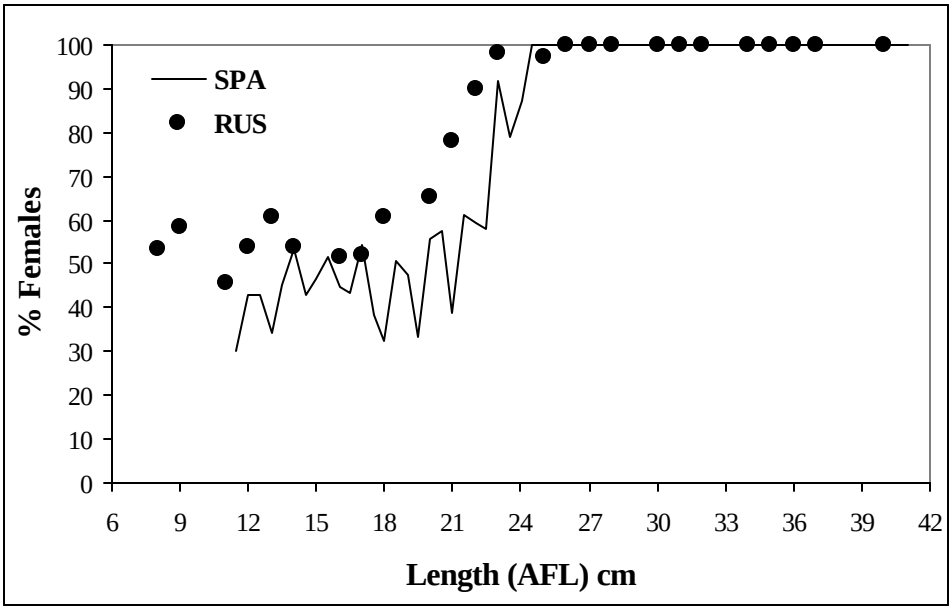


**Figure 4.-** Percentages of females at length in the Spanish and Russian roughhead grenadier commercial catches. A regression between total length and PFL (Atkinson 1991) was used to convert rughhead Russian length distributions into PFL.

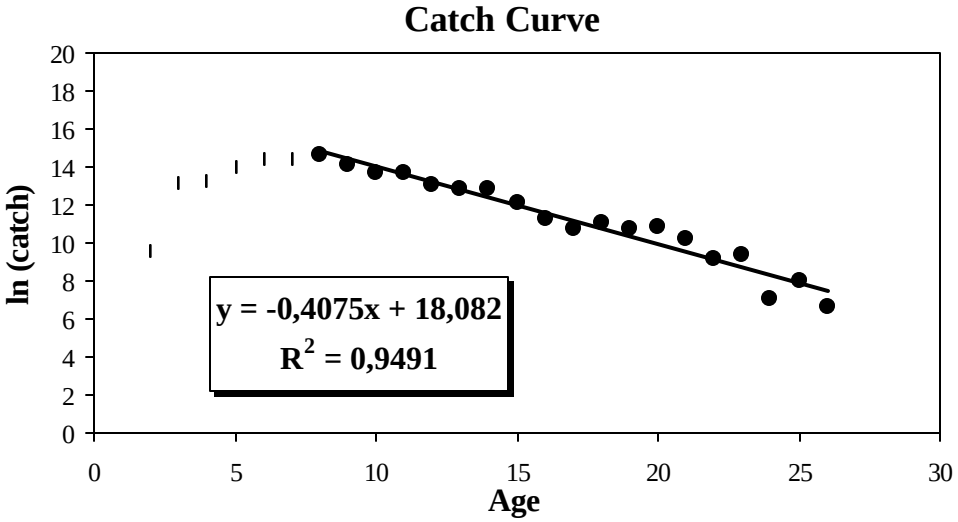


**Figure 5**.- Roughhead grenadier synthetic catch curve from the total catch of 1999 and Z estimate as the slope of the regression line for ages 9 and older.

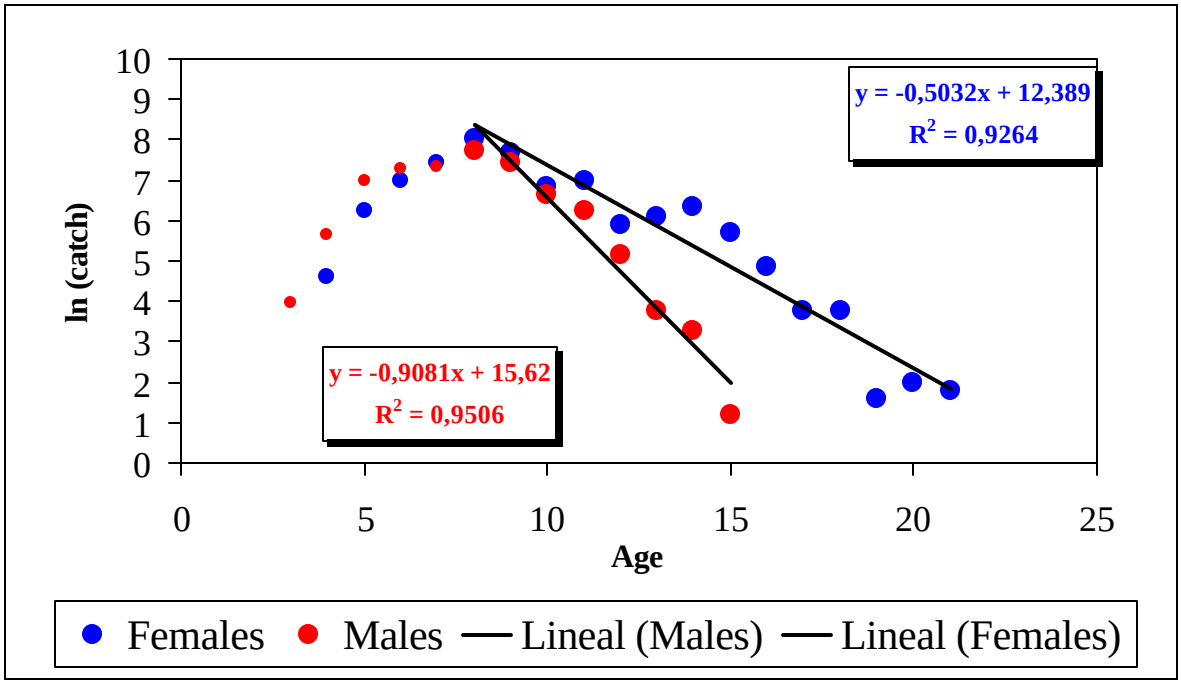


**Figure 6**. Roughhead grenadier synthetic catch curve by sex from the total catch of the pair-traw1 fleet in 999, Z estimate as the slope of the regression line for ages 9 and older.

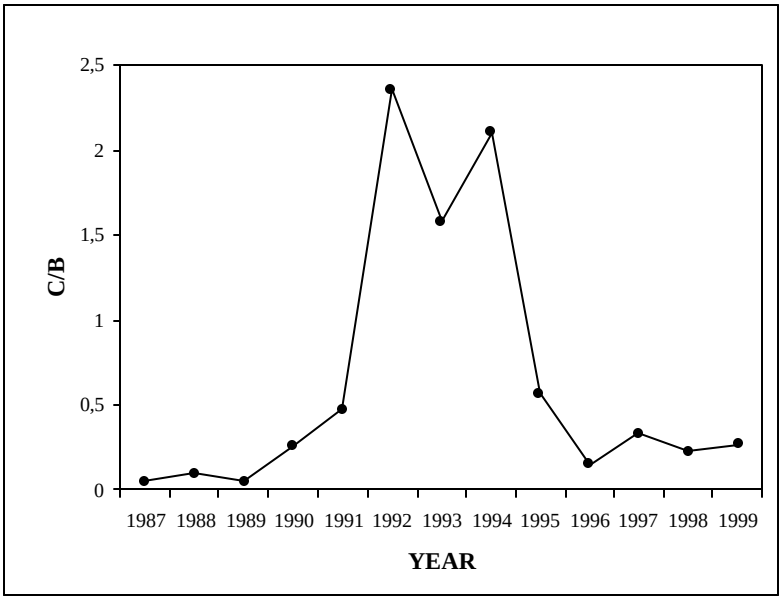


**Figure 7.-** Roughhead grenadier C/B Index.

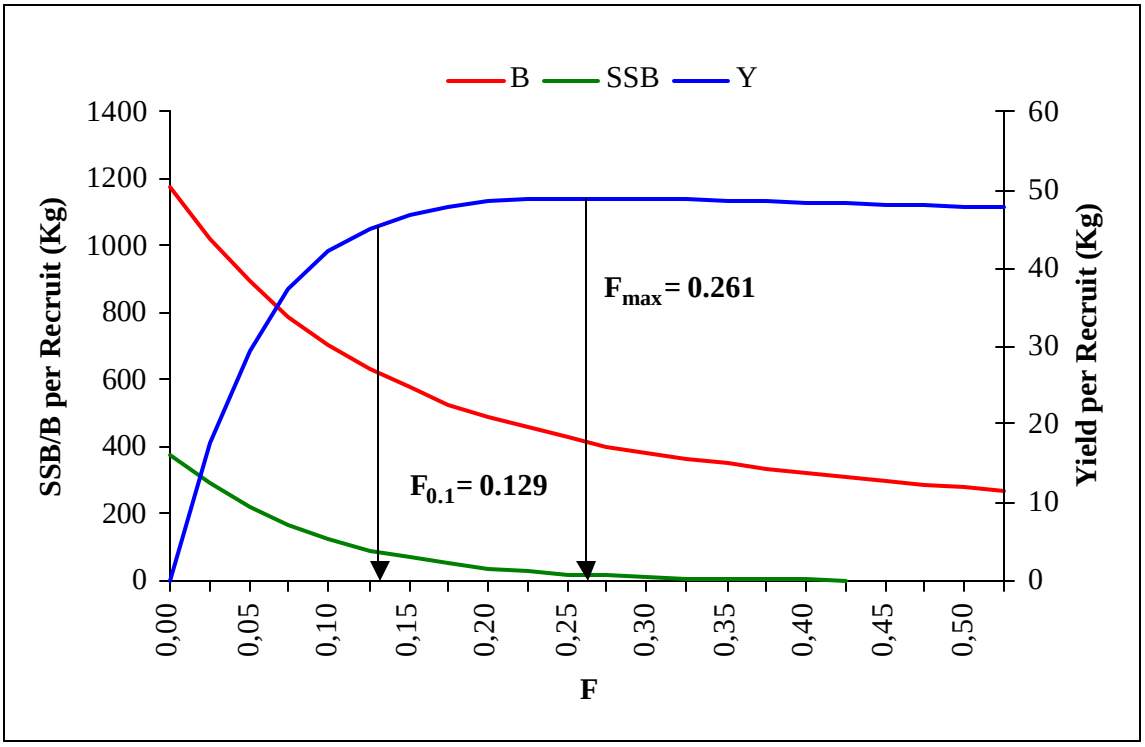


**Figure 8**. Roughhead grenadier yield per recruit analysis for roughhead grenadier ($M_{males}$= 0.6 and $M_{females}$ = 0.2).

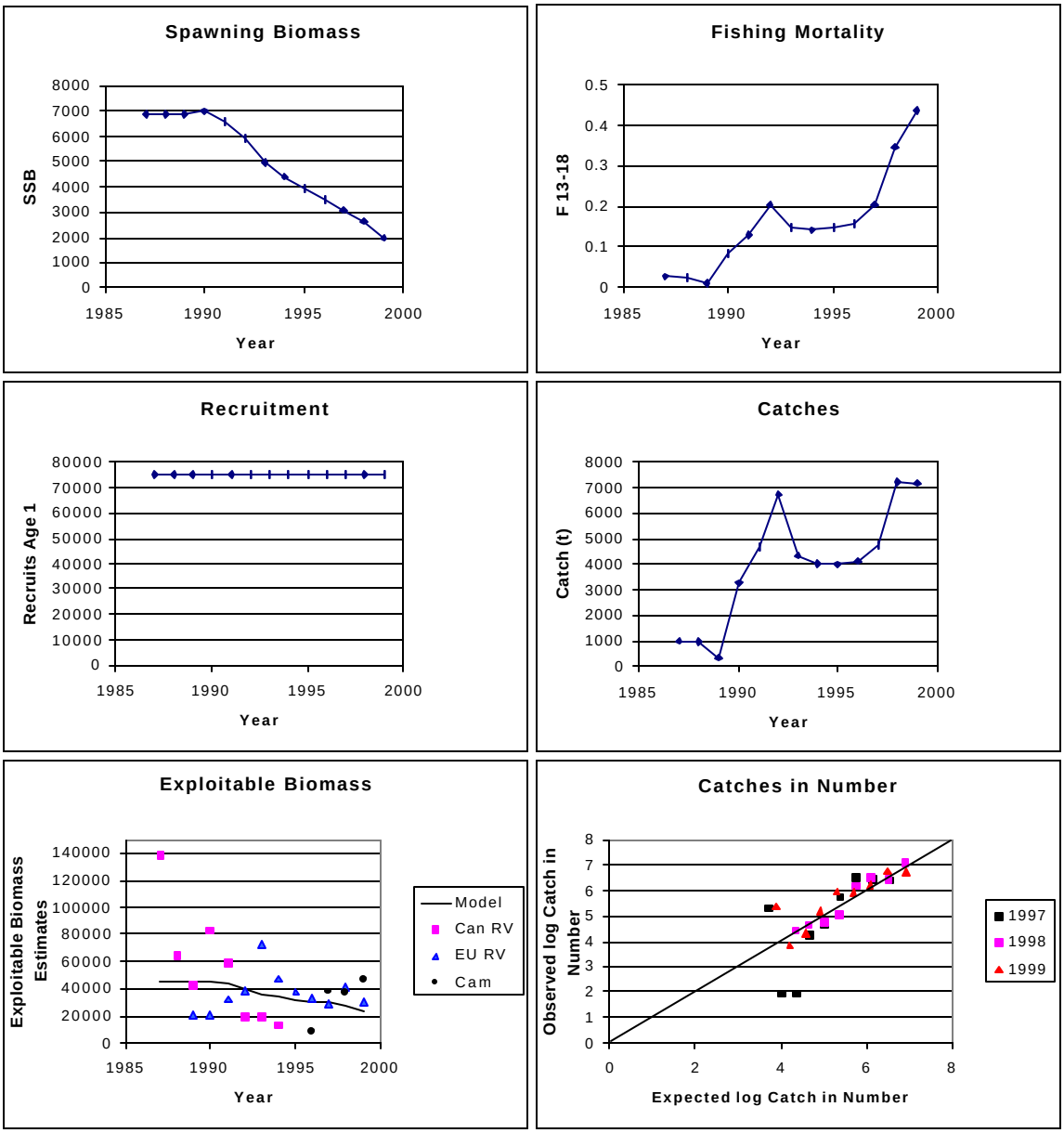


**Figure 9.** Summary results from trial age-structured production modelling.