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Northwest Atlantic Fisheries Organization

Serial No. N4863 **NAFO SCR Doc. 03/45**

SCIENTIFIC COUNCIL MEETING – JUNE 2002

An Assessment of Beaked Redfish (*S. mentella and S. fasciatus*) in NAFO Division Div. 3M

by

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Abstract

The present assessment evaluates the status of the Div. 3M beaked redfish stock, regarded as a management unit composed of two populations from two very similar species (*Sebastes mentella* and *Sebastes fasciatus*). The sum of the absolute length compositions of the 1989-2002 commercial catch with the 1993-2002 by-catch is the Div. 3M redfish catch at length input of this assessment. The VPA assessment used a 1989-2002 catch at age matrix starting at age 4 and having a plus group at age 19. An Extended Survivor Analysis (Shepherd, 1999) was performed using the previous XSA framework. The consistency of the XSA results was checked with a Retrospective Analysis confined to the assessments of the most recent years, 2002-2000. A logistic surplus production model (ASPIC) which does not use the equilibrium assumption (Praguer, 1994 and 1995) was also applied using the 1959-2002 catch coupled with the STATLANT standardised CPUE series (1959-1993) and the age 4 plus EU bottom biomass (1988-2002). The ASPIC results, as regards biomass and fishing mortality trends are comparable to the ones from the XSA but with biomass declining to a lesser extent and increasing at faster rate from 1998 onwards. Either XSA or ASPIC analysis pointed out that the Div. 3M beaked redfish stock experienced a steep decline from the second half of the eighties till 1996. Fishing mortality was kept well above F_{msy} over the first half of the assessment period. From 1995 onwards fishing mortality dropped and since 1997 has been kept well below the assumed natural mortality. Despite recent fluctuations biomass and female spawning biomass are generally increasing since 1997 but at slow rates, being still well bellow the levels of the first years of the time series. The stock reproductive potential has increased through the nineties compensating the SSB decline and sustaining a 1998-2002 geo-mean recruitment at age 4 identical to the former years of 1989-1993. The 1998 year-class at age 4, recruiting in 2002, is well above the 1989-2002 geo-mean recruitment (including both 1989 and 1990 above average year-classes). However by-catch mortality continued to act as a buffer on survival of pre recruits and its impact increases with the appearance of good year-classes such as the 1998 and the promising 2000 year-class. Short (2006) and medium term (20012) projections were made with the XSA survivors and recruitment randomly re-sampled, assuming two productivity scenarios: one including all recruitments (observed productivity) and the other excluding the recruitment peaks (low productivity). A single option of fishing mortality was considered, and corresponding to short term catches within an interval defined by the recent level of total catch of 4 000 tons and the actual TAC of 5 000 tons. Such option is given by 40% $F_{statuquo}$. Taking into account the trajectories of the last Mterm projections, further increase of the stock and spawning biomass will continue so far to be dependent on keeping fishing mortality at a low level, below both the assumed natural mortality and $F_{0.1}$. At the present stock size this should correspond to a level of catch not higher than 5 000 tons until the end of the present decade, regardless the recruitment regime that will prevail on the near future.

Summary

The Div. 3M redfish assessment is focused on the beaked redfish stock regarded as a management unit composed of two populations from two very similar species: the Flemish Cap *S. mentella* and *S. fasciatus*. The reasons for this approach are the dominance of this group in the Div. 3M redfish commercial catches, corresponding also to the bulk of the redfish bottom biomass survey indices available for the Flemish Cap bank (on average representing 80% of the redfish survey bottom biomass).

The redfish fishery on Div. 3M increased from 20 000 tons in 1985 to 81 000 tons in 1990, falling continuously since then till 1998-1999, when a minimum catch around 1 000 tons has been recorded. The increase of the redfish catches to 3 800 tons in 2000 may reflect the rebirth of a redfish directed fishery in Div. 3M, with EU-Portugal and Russia consolidating their major role on the actual fishery. In 2001 catch was at a somewhat lower level (3 295 tons) and this scenario is kept in 2002 with the same level of provisional catches (3 248 tons), shared by the same partners (Table 1a, Fig. 2a). The boom in 1993 and further settlement of a shrimp fishery in Flemish Cap lead to high levels of redfish by-catch in 1993-1994. Since 1995 this by-catch in weight fell to apparent low levels but in 2001-2002 redfish by-catch reached 738-767 tons, the highest level observed since 1994. Translated to numbers this represents an increase from an annual by-catch level of 3.8 millions of redfish, recorded in 1998-2000, to 22.1 millions in 2001-2002. In 1998-2000 this by-catch represented on average 44% of the total Div. 3M redfish catch in numbers. In 2001-2002 the redfish by-catch in numbers from the Flemish Cap shrimp fishery justified 71% of the total catch.

For several years length sampling data from Russia and from the Japan were available and used to estimate the length composition of the commercial catches for those fleets and time periods. The 1989-2002 length composition of the Portuguese trawl catch was applied to the rest of the commercial catches (Table 1b). The 1993-2002 redfish by-catch in numbers at length for the Div. 3M shrimp fishery was calculated based on data collected on board of Canadian and Norwegian vessels (Table 1c). The sum of the absolute length compositions of the 1989-2002 commercial catch with the 1993-2002 by-catch is the Div. 3M redfish catch at length input of this assessment (Table 1d, Fig. 2b).

The EU survey abundance and female mature abundance at length for Div. 3M beaked redfish were updated with the results from the 2002 survey (Saborido Rey and Vazquez, 2003), following the methodology used in previous assessments and described in detail in the section of Input data (Table 2).

Survey bottom biomass and survey female spawning biomass was calculated as sum of products based on the abundance at length from Canadian (1979-1985) and EU (1988-2002) bottom trawl surveys, and on the annual length weight relationships derived from EU survey data (Tables 2 and 3). The 1989-2002 EU survey mean catch per tow for Div. 3M beaked redfish is also presented, in Tab 2 and Fig. 6b, with the associated standard errors.

Both survey abundance (Table 4ab) and catch at age (Table 5, Fig. 3) matrices were obtained with annual *S. mentella* age length keys from the 1990-2002 EU surveys, both sexes combined.

The more recent period covered by EU surveys (1988-2002), started with a continuous decline of survey bottom biomass till 1991 followed by a period of biomass fluctuation with no apparent trend from 1992 till 1996. A further decline occurred in 1997 and 1998, when the second lowest survey biomass was recorded (Table 2, Fig. 6a). Survey bottom biomass increased in 1999 and 2000 till 110 000 tons, the highest index observed since 1989. In 2001 biomass fall again to 59,000 tons but increased to 86 000 tons in 2002.

Survey female spawning biomass declined through the first years of EU survey series, staying at low level between 8 000-9 000 tons for most of the years since 1993. Over the more recent period the SSB index experienced large inter-annual variation, from a minimum in 1998 of 3 700 tons to 19 500 tons recorded in 2000, the highest value since 1990. In 2001-2002 the SSB index returned to 7 000-8 000 tons. The wide oscillations in bottom biomass survey indices with time can be induced by changes on the adult redfish concentration near the bottom (fish grater than 30 cm generally speaking), as well as on the distribution of this component in and out of the survey swept area of the Flemish Cap Bank. Those changes are reflected on strong negative year effects on survey catchability through the full recruited age groups over the most recent years.

An Extended Survivor Analysis (XSA) (Shepherd, 1999) was performed using the 1989-2002 EU survey abundance at age as the tuning file. The 2001-2002 XSA framework remained unchanged: age 4 as the first age group and a plus group set at age 19; no tapered time weighting, no recruiting ages with catchability dependent of year-class strength, constant catchability just at the penultimate age and a minimum standard error of the log catchability for the last true age of 0.5.

The XSA converged after a high number of iterations, showing a high variability on survey catchability at age (Table 11) and a clear pattern of year effects (Table 11, Fig. 8a). Most of the *log* catchability residuals were positive during the intermediate years of 1994 to 1997, while on the former years till 1991 and again on 1998 and 2001-2002 most ages had negative residuals. Nevertheless the size of *log* catchability residuals over the most recent years (1999-2002) is smaller than through the preceding years (Fig. 8b). Low fishing mortalities from 1997 onwards, well bellow the assumed level of natural mortality, temporal changes on beaked redfish concentration near the bottom of the survey swept area (amplifying the noise on the *log* catchabilities at age and introducing strong year effects) together with a declining trend of catchabilty with age (Table 11), contributed to the long process of convergence.

The consistency of the XSA results was checked with a Retrospective Analysis. In order to preserve at the maximum extent most of the cohorts occurring from 1989 onwards, namely the 1990 year-class, this analysis is confined to the assessments of the most recent years, 2002-2000. The retrospective XSA present a moderate over bias pattern on biomasses and an under bias pattern on fishing mortality (Table 11b and Fig. 9abc). The last three assessments present close estimates of both fishing mortality and female SSB until 1996 and 1998 respectively. The 2003 XSA estimates for 2001 biomass, female SSB and fishing mortality are around +/- 20% of the correspondent 2002 assessment results. From the possible causes of retrospective patterns the year patterns in catchability, translated in high positive or negative *log* catchability residuals through most of the ages on several years, can be the main cause of bias in a redfish assessment. For the 2000-2002 assessments, where all the recruitments are estimated from the respective survivors, an over bias of the 1990-1995 cohorts at age 4 also shows up in the retrospective analysis (first age group of the XSA's, years 1994-1999; Table 11c and Fig. 9d). For weak year-classes the impact of such recruitment over bias, first on biomass and later on female SSB over bias, can be neglected. But recruitment over bias of a strong year-class, such as the one from 1990, will be foreseen. Namely if such a strong year-class is driving the biomass and SSB trends of a stock just leaving overexploitation with most of its cohorts depleted or weak.

In summary, the poor fit of the XSA model to the survey abundance at age seems related both with redfish own biology and recent low levels of fishing mortality below natural mortality. This poor fit is a burden any redfish / lightly exploited stock assessment has to carry when using VPA based models supported by survey tuning. Despite the long process of convergence, the year patterns in the residuals of cachability at age as well as the SSB and fishing mortality patterns of the retrospective analysis, the 2003 XSA results are not only consistent for the majority of years within the overlap assessment interval of the more recent XSA's but should also be regarded as the closest picture one can get of the actual Div. 3M beaked redfish stock size.

From the Extended Survivor Analysis results (Table 12 and Fig. 10abcd) very high fishing mortalities until 1996 forced a rapid and steep decline of either abundance, biomass and female spawning biomass of the Div. 3M beaked redfish stock. From 1997 onwards, low fishing mortalities allowed a discontinuous and slow growth of both biomass and SSB but abundance was kept stable at a low level from 1996 to 2001, only increasing in 2002 with the income of the above average 1998 year-class to the 4+ stock. There was a general increase of the stock reproductive potential from 1992 to 1998. However in 2002 female spawning stock biomass was still far away from a SSB level of 80 000 tons, beyond which two consecutive above average recruitments were observed in 1989 and 1990. At the same time the appearance of the first abundant year-class after 1990, the 1998 cohort, may suggest that above average recruitments can be expected at much lower SSB levels but this signal needs to be confirmed in future assessments.

A Separable/Cohort analysis (Pope and Shepherd, 1982) has not been performed in the present assessment. From previous assessment results (Ávila de Melo *et al*, 2002) when compared with XSA, the Cohort/SPA model systematically under estimated both stock biomass and spawning stock biomass. The comparison of the results between these two VPA based models confirmed that, in the case of Div. 3M beaked redfish, biomass and fishing mortality outputs from survey and commercial input data used in XSA and SPA respectively are not in contradiction, regardless a better pattern of fitness to catch at age by the SPA model. However SPA is not an autonomous model and should not replace a model such as XSA, with an independent tuning process for the objective computation of terminal fishing mortalities.

A logistic surplus production model (ASPIC) which does not use the equilibrium assumption (Praguer, 1994 and 1995) was also applied using the 1959-2002 catch coupled with the STATLANT standardised CPUE series (1959-1993) and the age 4 plus EU bottom biomass (1988-2002). ASPIC run first on the FIT mode, to have the deterministic parameters estimate together with effort and survey pattern of un-weighted residuals, as well as biomass and fishing mortality trends (expressed as ratios to B_{msy} and F_{msy}). On a second run on BOT mode effort and survey residuals were re-sampled 1000 times in order to derive bias corrected estimates and probability distribution of the parameters.

The ASPIC results (Table 13b, Fig. 11ab) shows small relative bias between the corrected and ordinary parameter estimates (0.2%-3.6%) indicating for most of the fitted parameters a distribution close to normality. The ASPIC corrected estimate for F_{msy} is 0.066, a fishing mortality level lower than $F_{0.1}$ (0.082) and similar to $F_{50\%SPR}$ (0.060), with an upper 50% confidence limit at the assumed natural mortality (0.1). As for MSY the ASPIC bias corrected estimate is of 16 800 tons with an inter quartile range for 50% confidence limits of 3 600 tons. As regards biomass and fishing mortality trends, ASPIC results are comparable to the ones from the previous XSA assessment. But on the final years of the time series the production model is not sensitive to the survey biomass fluctuations and with low fishing mortalities and a constant rate of increase ASPIC biomass grows faster than XSA biomass between 1999 and 2002 (Table 14, Fig. 11).

Either XSA or ASPIC analysis pointed out that the Div. 3M beaked redfish stock experienced a steep decline from the second half of the eighties till 1996. Fishing mortality was kept well above F_{msy} over the first half of the assessment period, due to increasing commercial catches since the mid eighties that reached a top level within 1989 and 1993. From 1995 onwards fishing mortality dropped and since 1997 has been kept well below natural mortality. Despite recent fluctuations biomass is generally increasing since 1997 but slowly, being still far away of the level estimated for the beginning of the time series (1989). The same irregular and discrete pattern of growth is observed on the female spawning biomass, also recovering from the 1996 minimum. The prospective of a no return increase of both biomass and SSB seems to consolidate under the present low exploitation regime: the stock reproductive potential has increased through the nineties (Fig. 10c) compensating the SSB decline and sustaining a 1998-2002 geo-mean recruitment at age 4 identical to the former years of 1989-1993. The 1998 year-class, recruiting in 2002, is well above the 1989-2002 geo-mean recruitment (including both 1989 and 1990 above average year-classes).

By-catch mortality continued to act as a buffer on survival of pre-recruits and its impact increases with year-class strength, as its is illustrated in the 2001-2002 length composition of redfish by-catch (Table 1b and c; Fig. 2b). The actual sorting grades are ineffective to avoid large amounts of by-catch of redfish of small sizes up to 14cm. With the availability to shrimp trawlers of the promising 2000 year-class (the most abundant year-class at age 1 and the second largest at age 2 of the 1988-2002 interval, from EU survey results) there is little doubt that a faster rate of stock growth, both in biomass and namely in abundance, is now dependent on the survival of this abundant cohort through its early life stage preceding recruitment to commercial fishery. Keeping catch and fishing mortality at a low level can only be effective in supporting a medium term faster stock recovery if measures to drastically reduce by-catch of very small redfish are implemented in the short term.

Short (2006) and medium term (2012) projections were made with the XSA survivors and recruitment randomly re-sampled, assuming two productivity scenarios: one including all 1989-2002 recruitments from XSA (observed productivity, Table 15a) and the other excluding the 1989, 1990 and 1998 XSA recruitment peaks (low productivity, Tab 15b). A single option of fishing mortality was chosen, corresponding to short term catches within an interval defined by the recent level of total catch of 4 000 tons and the actual TAC of 5 000 tons. Such option is given by 40% $F_{statuquo}$ (= $Fbar_{2002}$, average fishing mortality for ages 6 to 16) regardless the adopted productivity regime.

Results are presented for short and medium term SSB for a range of fishing mortalities around 40% $F_{statuquo}$ and under each of the productivity scenarios, respectively on Table 16a/Fig. 12ab and Table 16b/Fig. 13ab). The 2003-2012 spawning biomass trajectories keeping fishing mortality at 40% $F_{statuquo}$ and under each of the productivity scenarios are presented on Table 17a and Fig. 14ab. The correspondent yield trajectories are presented on Table 17b and Fig. 15ab.

A 40% reduction on $F_{statuquo}$ will keep, for most of the present decade, catches anchored between their present level and the adopted 2000-2003 TAC, but at the same time will allow, with a high probability (20^{th} % probability profile) a 50% increase of the actual female spawning stock biomass by 2006 and a 2011 SSB representing at least 80% of the female SSB level estimated for the start of the time series. The Mterm results also suggest that the impact on biomass and catch of either productivity scenarios is null on the short term. However within the next ten years the same fishing mortality regime will drive female SSB closer to a safe level of 80 000 tons if similar pulses of recruitment continue to occur in the near future and are allowed to reach age 4 still as strong year-classes. At the same time, and at the same level of fishing mortality, catches will have more room to gradually increase from 2009 onwards if recruitment follows the observed productivity pattern of the last 14 years (Table 18, Fig. 16ab).

In conclusion further increase of the stock and spawning biomass will continue so far to be dependent on keeping fishing mortality at a low level, below both the assumed natural mortality and $F_{0.1}$. At the present stock size and taking into account the trajectories of the last Mterm projections, this should correspond to a level of catch not higher than 5 000 tons until the end of the present decade regardless the recruitment regime that will prevail on the near future.

Introduction

The Flemish Cap is an underwater plateau located around 47ºN and 45ºW east of the Grand Bank of Newfoundland, with 10 555 squared miles. It has a minimum water depth of 125 m in the centre and is separated from the Newfoundland shelf by the Flemish Pass, a region with minimum depth of about 1 100 m (Fig. 1a). This physical barrier contributed to the isolation of some of the Flemish Cap fish populations, restraining the migration of species concentrating in depths less than 700 m. The Flemish Cap bank is completely outside the 200 miles Economic Zone of Canada and inside the NAFO (Northwest Atlantic Fisheries Organization) Regulatory Area, in statistical Div. 3M.

There are three stocks of redfish in NAFO Div. 3M: deep-sea redfish (*Sebastes mentella*) with a maximum abundance at depths greater than 300 m, golden redfish (*Sebastes marinus*) and Acadian redfish (*Sebastes fasciatus*) preferring shallower waters of less than 400 m. Due to their external resemblance *S. mentella* and *S. fasciatus* are commonly designated as beaked redfish. All stocks have both pelagic and demersal concentrations as well as a long recruitment process to the bottom, extending to lengths up to 30-32cm. The identity of the Flemish Cap beaked redfish populations is supported by recent morphometric studies, which detected significant differences (at $p<0.01$) between the otolith length of both *S. mentella* and *S. fasciatus* from the Flemish Cap bank and the Newfoundland and St. Pierre banks (Saborido Rey, 1998).

The Flemish Cap redfish species are long living and present a slow growth, with fish attaining a size around 20-22cm at 5 years old and reaching 30 cm only at age 10. The Flemish Cap *S. mentella* and *S. fasciatus populations* present a similar length growth, namely the females of the two species, up to 20 years of age (Saborido Rey, 2001). All species are viviparous with the larvae eclosion occurring right before or after birth. Mean age of female first maturation varies from 8 years (mean length of 26.5 cm) for Acadian redfish, 10 years (mean length of 30.1 cm) for deep-sea redfish, and 12 years (mean length of 33.8 cm) for golden redfish. Spawning on Flemish Cap occurs through February till the first half of April for deep-sea and golden redfish while for Acadian redfish spawning reach its maximum in July-August (Saborido Rey, 1994).

Due to the similarity of their external morphology the commercial catches of Div. 3M redfish have always been reported together. Only since 1992 the deep-sea and Acadian redfish survey catches are separated by species on the Flemish Cap/EU bottom trawl surveys. However on the other Northwest Atlantic survey series, namely the Canadian and Russian ones, those two species are treated together as beaked redfish. Deep-sea redfish dominate the redfish commercial catches on Div. 3M, due not only to its higher abundance but also to its higher value in the Asian markets, while the golden redfish was mainly taken as a by-catch of the former Flemish Cap cod fishery.

The Div. 3M redfish assessment is focused on the beaked redfish stock regarded as a management unit composed of two populations from two very similar species: the Flemish Cap *S. mentella* and *S. fasciatus*. The reasons for this approach are the dominance of this group in the Div. 3M redfish commercial catches, corresponding also to the bulk of the redfish bottom biomass survey indices available for the Flemish Cap bank (on average representing 80% of the redfish survey bottom biomass). Finally, and due to market demand reasons, any recovery of the Div. 3M redfish fishery will be dependent on the recovery of the *S. mentella* plus *S. fasciatus* biomass from recent overexploitation.

Beaked redfish presents a geographical distribution wider than other Flemish Cap resident fish stocks, with most of its biomass spread within the boundaries of the eastern 800m-depth contour of the Flemish Cap bank, the southwest shallower bottoms of the Beothuk Knoll and the north-eastern slopes of the Flemish Pass. It should also be noted that over the second half of the 1990s to early-2000s an unknown proportion of the Div. 3M redfish catches were taken as by-catch of the Greenland halibut fishery pursued on the slopes of both sides of the Sackville Spur corner, on the Grand Bank side of the Flemish Pass but already in Div. 3M (Fig. 1). These catches don't belong to the Div. 3M beaked redfish stock but to the neighbour *S. mentella* population of Div. 3L. However, due to the difficulty to apart these catches from the true Div. 3M redfish catches all catch allocated in Div. 3M was considered in the assessment as a catch from the Div. 3M beaked redfish stock.

The present assessment uses an Extended Survivor Analysis (XSA) to tune the terminal fishing mortalities at age (F 's at age) with the EU survey abundance's at age and to estimate the survivors by the end of 2002. This analysis is then compared a non-equilibrium surplus production model (ASPIC) for checking the consistency of the respective biomass trends. With the XSA survivors and recruitment randomly re-sampled from the 1999-2001 geometric mean-, short- and medium-term projections were made for a short-term catch status quo assumption. Low and observed productivity medium term scenarios were considered as regards recruitment.

Description of the fishery

The Div. 3M redfish stocks have been exploited over the past both by pelagic and bottom trawl. Due to the similarity of their external morphology the commercial catches of Div. 3M redfish are reported together. The majority of the bottom commercial catches are composed of beaked redfish. The species composition of the pelagic redfish catches, which dominated the fishery in the early nineties, remains unknown. However, taking into account that from survey results, *S.mentella* and *S.fasciatus* together represent the major proportion of the abundance and biomass of Div. 3M redfish it is assumed that these pelagic catches were also dominated by beaked redfish.

The redfish fishery on Div. 3M increased from 20 000 tons in 1985 to 81 000 tons in 1990, falling continuously since then till 1998-1999, when a minimum catch around 1 000 tons has been recorded most as by-catch of the Greenland halibut fishery (Table 1a, Fig. 2a). The drop of the Div. 3M redfish catches from 1990 onwards is related with the quick decline of the stock biomass followed by an abrupt decline of fishing effort deployed in this fishery.

Mid-water trawlers from Russia and the Baltic states conducted the fishery from 1989 to 1993 (these later fleets only showing up in 1992 and 1993), followed by bottom trawlers from EU-Portugal, South Korea (which entered the fishery in 1989with a peak of 17 885 tons) and Cuba (Table 1a). However the leading role of Russia in the fishery is lost in 1992, when the respective catches fall to 2 937 tons, from 24 661 tons caught in the previous year. The Baltic fleets almost vanished from Flemish Cap in 1994 and so did South Korea.

In 1994 and 1995 the Div. 3M redfish fishery dropped to a level of 11 000-13 500 tons, with Russia and Portugal being still the main participants in the fishery. Estimated Div. 3M redfish catches from non-Contracting Parties represented 13% and 26% of the overall catch respectively. Most of these catches, as well as the Portuguese catches, were taken as by-catch of the former Div. 3M cod trawl fishery.

In 1996 the Div. 3M redfish catch continued to decline to 5 800 tons. Most of it taken by Korean crewed non-Contracting Party vessels (4 150 tons, from Canadian surveillance reports) indicating that, although with reflaged vessels, South Korea was still interested in Div. 3M redfish. Japan (678 tons) and EU-Portugal (332 tons) were the major Contracting Parties with redfish catches recorded in 1996.

The remaining Portuguese and Japanese trawlers recorded the major proportion of the catch from 1996 till 1999, but for these fleets Greenland halibut was already the priority species in all NAFO Divisions (NAFO circular letters with monthly provisional catches, 1995-1999). During this period most of the Div. 3M redfish catches were actually taken as by-catch of the Greenland halibut fishery.

However in 1999 Russian vessels appeared again in Flemish Cap and their nominal catch rose from 92 tons to 1 808 tons in 2000. Estonians vessels joined the fishery in 2000 recording 632 tons, while the EU catches increased from 505 tons in 1999 to 1349 tons in 2000 due to a jump in the catches from Portugal: 96 tons to 916 tons. The increase of the redfish catches from 1 068 tons in 1999 to 3 825 tons in 2000 may reflect the rebirth of a redfish directed fishery in Div. 3M. In 2001 provisional catches were at a somewhat lower level, 3 295 tons, but EU-Portugal and Russia consolidated their role as major partners of the actual fishery with 92% of the overall catch. This scenario is kept in 2002 with the same level of catches (3 248 tons) shared by the same partners (NAFO circular letters with monthly provisional catches, 2000-2003).

The boom in 1993 and further settlement of a shrimp fishery in Flemish Cap lead to high levels of redfish by-catch in 1993-1994. The loss of commercial yield of beaked redfish due to the 1993-1995 by-catches by the Div. 3M shrimp fishery was calculated to be at 23 000 tons, for an exploitation level around $F_{0.1}$ (Ávila de Melo *et al*., 1997). For this overall figure the 1993 by-catch contributed with 63% of the yield loss while the 1995 by-catch is only responsible for 3%. In terms of year-classes the 1989 year-class was the one with a major contribution to this overall yield loss (49%), followed by the 1990 year-class (30%).

Since 1995 this by-catch in weight fell to apparent low levels but in 2001-2002 redfish by-catch reached 738-767 tons (Kulka, 2002 and 2003, *pers. comm.*), the highest level observed since 1994. Translated to numbers this represents an increase from an annual by-catch level of 3.8 millions of redfish, recorded in 1998-2000, to 22.1 millions in 2001-2002. In 1998-2000 this by-catch represented on average 44% of the total Div. 3M redfish catch in numbers. In 2001-2002 the redfish by-catch in numbers from the Flemish Cap shrimp fishery justified 71% of the total catch.

Recent catches and by-catch ('000 tons) are as follows:

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
TAC	20	50	50	43	30	26	26	26	26	20	13	5	5	5
Catch	58.1[1]	81.0[1]	48.5[1]	43.3[1]	29.0[1]	11.3[1]	13.5[1]	5.8[1]	1.3	1.0	1.1	3.8[2]	3.3[2]	3.2[2]
By-catch[3]					11.97	5.90	0.37	0.55	0.16	0.19	0.10	0.10	0.74	0.77
Total	58.1	81.0	48.5	43.3	41.0	17.2	13.9	6.4	1.5	1.2	1.2	3.9	4.0	4.0

[1] Includes estimates of non-reported catches from various sources
[2] Provisional
[3] Kulka, D. pers. comm. 2000-2003

Research Survey Series

Bottom trawl survey biomass for Div. 3M redfish present large inter-annual variability, too drastic to be only explained by changes in stock abundance from one year to the next. These fluctuations are caused not only by vertical migrations of redfish, all species with both demersal and pelagic behaviour, but also by a wide and variable distribution within the division, as pointed out by the beaked redfish commercial catches from the north eastern slopes of Flemish Pass, near the border of Div. 3M with Div. 3L.

There are two survey series providing bottom biomass indices as well as length and age structure of the Flemish Cap redfish stocks: one from Russia (1983-1993; 1995-1996 and 2001-2002), one from the European Union/Spain and Portugal (1988-2002). An earlier bottom trawl survey series has been carried out by Canada from 1979 till 1985. This series was discontinued since then, despite an isolated Canadian bottom trawl survey conducted again on 1996.

Russian Series

The Russian survey has been conducted annually in April-May as a bottom trawl survey down to the 731 m depth contour from 1983 to 1995, with an interruption in 1994. During this first period the Russian bottom trawl survey series used the stratification of the Flemish Cap bank proposed by Doubleday (1981) and has been complemented with an acoustic estimate of the pelagic component of the redfish stocks between 1988 and 1993. In 1996 the Russian bottom trawl survey has covered for the first time the strata within 731-914m depth range, according to the Flemish Cap/Flemish Pass stratification proposed by Bishop (1994) (Igashov and Vaskov, 1997). The Russian series was again interrupted between 1997 and 2000. In May-June of 2001 and 2002 a bottom trawl survey was conducted by Russia on Flemish Cap and neighbouring grounds in Div. 3M, using Bishop’s stratification (*op. cit*) and with hauls down to 1 280m (Vaskov, 2002; Vaskov and Igashov, 2003).

On top of the discontinuity of this series there is a high variability in the way the Russian surveys were conducted, namely through the nineties. In 1992 four strata on the east-west southern limits of the Flemish Cap bank were not swept. Also since 1992 the number of valid tows dropped from 100-130 (1987-1991) to 53-76 (1992-1996). At least in 1996 the number of sets in most of the strata was kept constant (3 tows per strata). In 2001 and 2002 only 90-94 valid hauls were made within an area of 15 760 squared miles (an area about 50% greater than the area of the Flemish Cap bank covered by the EU series) (Vaskov, *op.cit.*) Survey vessels changed annually since 1991 (Vaskov and Igashov, *op. cit.*). Survey data till 1993 referred to the tree redfish species combined, whereas from 1995 onwards separate data are available for golden redfish (*Sebastes marinus*) and for beaked redfish (*Sebastes mentella* and *Sebastes fasciatus*).

Those changes from one year to the next, together with a poorer coverage of an increasing swept area, led the Russian bottom trawl series with an associated inter-annual variability higher than EU survey series. The discrepancies observed on several years between the survey results from the Russian and EU series are also too dramatic to be explained by seasonal changes in redfish distribution. These discrepancies are supported by differences on the strata (and depths) with a higher proportion of redfish biomass estimated by each of the surveys, which are difficult to justify taking into account the relatively short time lag between them. The above-mentioned facts had prevented the use of Russian data in the calibration procedures included in the assessment framework.

EU Series

The EU survey has been conducted annually in June-July since 1988 as a bottom trawl survey, down to the 731 m depth contour. Swept area is divided according the Flemish Cap bank stratification proposed by Doubleday (1981). Half an hour valid hauls were kept around 120 each year, with the number of hauls in each stratum proportional to the respective swept area. Each haul swept the bottom at a constant speed about 3.3-3.5 knots, with the gear performance controlled at most of the tows with SCANMAR equipment. Different survey vessels were used only in 1989 and 1990. During the 1988 and 1989 surveys only golden redfish has been separated from the rest of the redfish catches. Since 1990, juvenile redfish (less than 21 cm) has also been separated as an independent category, and 1992 forward all the 3 species and juveniles were separated in each haul catch prior to sampling procedures. However, with the continuation of these surveys, the skill to identify redfish smaller than 21 cm increased. The juvenile redfish that has been identified is directly allocated in its species catch, contributing to the decreasing of the proportion of small redfish classified as juvenile over the most recent years.

Canadian Series

A former Canadian bottom trawl survey series on Flemish Cap has been conducted from 1979 till 1985 in January-February months. The respective abundance estimates for Div. 3M beaked redfish (Power and Atkinson, 1986) were found to be within the same range of magnitude than the ones found on the following EU series.

An isolated bottom trawl survey was again conducted by Canada on Flemish Cap during autumn 1996, the first one since 1985 (Brodie *et al*., 1997) The survey used a stratification scheme down to 1462 m (Bishop, 1994) and was carried out by 2 vessels using the same fishing gear, one covering the strata till 731 m and the other covering the deeper strata, but just on the western and northern slopes of the bank. Sets were allocated proportionally to the stratum area except on the strata deeper than 731 m, were 2 sets were made on each of the covered stratum regardless their swept area.

Considering only the strata till 731m-depth contour there was reasonably good agreement between the biomass estimates from the Canadian survey and the EU survey for both golden and beaked redfish. There was also a good match between the strata where most of the redfish biomass was found on both 1996 surveys (Ávila de melo *et al*, 1997).

Input Data

Length composition of the commercial catch and by-catch

Most of the commercial length sampling data available for the Div. 3M redfish stocks came, since 1989, from the Portuguese fisheries and has been annually included in the Portuguese research reports on the NAFO SCS Document series (Alpoim *et al*., 2003). Most of these data referred to beaked redfish, and, taking into account that the majority of the length sampling was from depths greater than 400m, they should represent *S. mentella* catches. Length sampling data from Russia (1989-91, 1995, 1998-2002; Vaskov, A. *pers. comm.* 2000-2003; Vaskov et al., 2003) and from the Japan (1996 and 98; Ichii, T. *pers. comm.* 2001) were used to estimate the length composition of the commercial catches for those fleets and time periods. The 1989-2001 per mille length composition of the Portuguese trawl catch was applied to the rest of the commercial catches. In all cases the Div. 3M beaked redfish length weight relationships from 1989-2002 EU surveys (Saborido-Rey *pers. comm.*, 2000-2003) were used to compute each absolute length frequency vector of the Div. 3M redfish commercial catches (Table 1b).

Redfish by-catch in weight and in numbers at length for the Div. 3M shrimp fishery were available for 1993-1997, based on data collected on board of Canadian and Norwegian vessels (Kulka, 1999 and *pers. comm.*, 2000-2001). The 1998-2002 by-catch in number at length was derived from the 1998 Norwegian and 1999-2002 Canadian length sampling (Kulka, pers. *comm.*, 2001-2003). To abide the by-catch in number at length to both the total by-catch in weight and the EU survey length weight relationships used in the assessment (Table 3), the absolute length frequencies of the redfish by-catch for 2002 were calculated as in previous assessments (Ávila de Melo *et al*. 2000):

1. The redfish sampled by-catch in weight was estimated again, now as the sum of products of the absolute length frequencies of the sampled by-catch and the expected mean weight of each (1cm) length class.
2. The mean weight of the redfish by-catch was given by the ratio of the new estimate of the sampled by-catch in weight (sum of products estimate) and the sampled by-catch in numbers (sum of the absolute length frequencies).
3. A total by-catch in number is given by the ratio of the total by-catch in weight and the mean weight in the by-catch calculated previously.
4. The absolute length frequencies of the by-catch are converted in per mile length frequencies.
5. The final vector of by-catch in numbers at length is given by the extrapolation of the per mile length frequency vector by the estimate of total by-catch in number (thousands).

Length composition of redfish by-catch in the Div. 3M shrimp fishery is presented on Table 1c. The sum of the absolute length compositions of the 1989-2002 commercial catch with the 1993-2002 by-catch is the Div. 3M redfish catch at length input of this assessment (Table 1d). The generalised fall of the larger commercial sizes (>30 cm) during the first half of the nineties, the impact of the sorting grades in reducing from 1993 to 1996 the absolute length frequencies of the redfish by-catch and finally the dominance of the very small sizes (9 cm-14 cm) in the total catch whenever a relative abundant year-class appears (as it seems to be the case for the 2000 cohort) are well illustrated in Fig. 2b.

Length composition of the stock and spawning stock survey abundance

The 1988-2002 EU survey abundance and mature female abundance at length for Div. 3M beaked redfish, reflecting the relative importance of *S. mentella* and *S. fasciatus* in the whole of the two species, was calculated as follows:

1. For *S. mentella* and *S. fasciatus* (1992-2002) separately, and for beaked redfish (1988-1991), total and female abundance at length were recalculated in order to include smaller redfish classified in the EU surveys as juveniles. For each species this category was calculated through the 1992-2002 period from the respective absolute length frequency files of the Flemish Cap survey database (Vazquez, pers. comm., 2000-2003). For each year of this interval there is a file for each species (*S.marinus*, *S. mentella* and *S. fasciatus*) with the absolute length frequencies for males, females and unsexed juveniles, as well as another file with the length frequencies of unidentified juveniles.

   The average proportion of each species found in the identified juveniles was then applied to the length frequencies of unidentified juveniles in order to split them by species. A female ratio of 0.5 was finally applied to the juvenile length frequencies in order to have on an annual basis, and for each one of the beaked redfish species separately, numbers at length for females and total (both sexes combined), juveniles included. The same procedure was applied for the 1990-91 years when the survey redfish catches were split in golden redfish, beaked redfish and juveniles. On 1988-89 juveniles have not been considered a separate category in the survey catch and so total and female abundance at length including juveniles is given directly by the survey results.

2. From 1992 till 2002 mature female abundance at length for *S. mentella* and *S. fasciatus* is given each year by the respective length maturity ogives. These ogives are based on the histological analysis of gonads collected on the 1992 February-March cod tagging EU survey and on the 1992-93 June–July EU bottom trawl survey (Saborido-Rey, 1994). However the *S. mentella* length maturity ogive adopted for 1999-2001 is based in the histological analysis of gonads collected during the 1999 EU survey (Saborido-Rey, *pers. comm.* 2000).

To avoid the appearance of mature females at unrealistic young ages the expected mature female proportions were set at zero for lengths smaller than 21cm. Both beaked redfish total and mature females at length for the 1992-2002 period are the sum of the respective *S. mentella* and *S. fasciatus* sets first calculated by species.

3. A combined length maturity ogive was calculated in 2001 (Ávila de Melo *et al*, 2001) from the 1992-2000 female and mature female survey abundance at length of *S. mentella* and *S. fasciatus* (Table 4, Fig. 8). For the early years of the survey series (1988-1991), when beaked redfish EU survey catches were not separated by species, this ogive has been used to derive the mature female abundance's at length from the correspondent beaked redfish female survey abundance at length.

For the 1979-85 Canadian surveys (Power and Atkinson, 1986) beaked redfish total abundance at length is given directly by the survey results (Table 5). A mature female proportion at length, given by the product of the EU survey female ratio and the combined beaked redfish maturity ogive at length (Table 4, Fig.8), was applied to the 1979-85 total abundance at length in order to obtain the correspondent mature female abundance at length for the Canadian survey series (Table 2).

Length weight relationships

Length weight relationships for each of the Div. 3M beaked redfish species separately (1991-2002) and for *S.mentella* and *S. fasciatus* combined (1989-2002) were calculated with survey length-weight data from both sexes (Saborido Rey *pers. comm.*, 2002-2003) and used in the assessment on an annual basis (Table 3).

Survey indices

Survey biomass and female spawning biomass were calculated as sums of products of survey abundance and mature female abundance at length times mean weight at length. Beaked redfish (1988-91), *S.mentella* and *S. fasciatus* (1992-2002) length-weight relationships were used in the EU series (1988-2002), while a general length-weight relationship representative of the 1989-2000 interval was applied to the former Canadian series (1979-85) (Table 2 and 3).

The 1989-2002 EU survey biomass index for Div. 3M beaked redfish is also presented as the mean catch per tow and associated standard errors (Table 2). This mean catch is the sum of the mean catch per tow for S. mentella, S. fasciatus (Saborido Rey and Vazquez, 2003) and beaked redfish juveniles. The mean catch per tow for beaked redfish juveniles is estimated with the proportion of beaked redfish found in the sum of products biomass for small redfish up to 21cm length. The standard error is given by the square root of the sum of squares of the standard errors associated to each mean catch per tow.

Age composition of the beaked redfish survey stock and mature female beaked redfish stock

The EU survey abundance at age for the 1989-2002 Div. 3M beaked redfish stock and mature female component (Table 4ab) were obtained using the *S.mentella* age length keys from the 1990-2002 EU surveys, with both sexes combined. Dr. Fran Saborido-Rey (Instituto de Investigaciones Marinas,Vigo, Spain) has carried out age reading of Div. 3M redfish otoliths since 1990 (Saborido-Rey, 1994). Due to the fact that the 1989 *S.mentella* age length key was based on scale readings, the 1990 *S. mentella* age length key was also used in 1989. The ageing criteria of Div. 3M redfish otoliths have been first revised in 1995 (Saborido-Rey, 1995) and all survey age length keys were then standardised accordingly.

However an inconsistency was detected on the intermediate years, between the inter-annual shift of the *S. mentella* survey length distributions and the age assigned every year to each modal length group. The survey *S. mentella* otoliths from the modal length intervals between 14 and 26 cm of the 1994-1997 age-length keys were again revised in 1998 (Saborido Rey *pers. comm.*, 1998). The new proportions of age at length were used to re-build the 1994-1997 age-length keys that were used in this assessment together with the un-revised ones (1990-1993 and 1998-2002) in order to transform both catch and survey abundance at length of the Div. 3M beaked redfish into their correspondent age composition. With the new ageing, a clearer consistence exists for the follow up of the strong 1990 cohort. It is noticeable that this year-class shows a density dependent growth (Saborido-Rey, 2001). Due to the scarcity of redfish larger than 40cm either in the survey and commercial catch a plus group was considered at age 19.

Age composition of the catches

Age composition of the total catches, including the redfish by-catch on the Div. 3M shrimp fishery, was also obtained using the *S.mentella* age length keys from the 1990-2001 EU surveys (Table 5). The shift of the relative age composition of the catch towards the smallest age groups (1-3) from the early (1989-1991) to the most recent years (2000-2002) of the assessment is illustrated in Fig. 3.

Mean weights at age

The annual beaked redfish length weight relationships from EU survey (Table 3) were used to calculate mean weights at age both in the Div. 3M redfish total catches (commercial plus by-catch) (Table 6) as well as in the Div. 3M beaked redfish stock and female spawning stock (Table 7).

Partial recruitment vector

The partial recruitment vector (PR) was first derived from the total mortality at age estimated from the *S. mentella* survey abundance at age (Ávila de Melo *et al.*, 1997 and 1998). This former vector, suggesting a dome shape exploitation pattern, was considered unrealistic by the Scientific Council. The computation of the partial recruitment vector was further revised in 1999 (Ávila de Melo *et al.*, 1999) assuming a flat top partial recruitment.

In order to generate an observed partial recruitment vector an Findex was derived first from the 1989-2002 ratios between the sums of the per mile Div. 3M redfish total catch (commercial plus by-catch) and the per mile beaked redfish survey abundance at age (Atkinson, 1998, *pers. comm.*). Those indicators of F at age were then standardised to its highest value, recorded at age 13. This observed partial recruitment vector was then adjusted to a general logistic curve for ages 5 to 18 (Table 8a, Fig. 4).

The expected exploitation pattern was finally used in the yield per recruit analysis. However, due to the impact of the shrimp fishery on the mortality of the youngest age groups, the observed PR for ages 1 to 4 was adopted in the long-term projections.

Maturity ogive

An observed maturity ogive for Div. 3M beaked redfish was calculated as the mean proportion of mature females in the survey stock abundance at age (Table 4c) and used in VPA based methods to get female spawning biomass estimates. At each age this mean proportion is given by the ratio between the 1989-2002 sum of survey mature females and the correspondent total survey stock abundance. This observed maturity ogive was also fitted to a general logistic curve in order to give an expected maturity ogive for the spawning stock per recruit analysis (Table 8b, Fig. 5).

Vectors used in yield per recruit analysis

A Div. 3M beaked redfish yield per recruit analysis was conducted incorporating the following sets of vectors (Table 8c), all of them considered to be representative, in terms of growth and maturity, of beaked redfish as a whole throughout the assessment period (1989-2002):

1) Mean weights at age in the commercial catch.
2) Mean weights at age in the stock (as well as in the mature female component) from length weight relationships and from stock survey abundances.
3) Female maturity ogive at age, from the mature female and stock survey abundance at age.
4) Expected partial recruitment vector (though keeping the observed PR at ages 1-4).
5) Natural mortality, set at 0.2 for ages 1 and 2 to allow a higher juvenile mortality. Assumed to be constant at 0.1 for older ages.

Assessment Results

Bottom biomass, spawning biomass and abundance from EU bottom trawl surveys (1988-2001) and Canadian bottom trawl surveys (1979-1985)

The more recent period of 1988-2002, covered by EU surveys, started with a continuous decline of bottom biomass till 1991 followed by a period of biomass fluctuation with no apparent trend from 1992 till 1996. A further decline occurred in 1997 and 1998, when the second lowest biomass was recorded (Table 2, Fig. 6a). Survey bottom biomass increased in 1999 and 2000 till 110,000 tons, the highest index observed since 1989. In 2001 biomass fall again to 59,000 tons but increased to 89,000tons in 2002. This fall in 2001 is also reflected in the spawning biomass index, reduced to 7,000 tons after being at 19,500 tons just the year before. In 2002 this survey index was still kept at 7,900tons. It is difficult to associate those drastic declines with fishing mortality, well bellow the assumed natural mortality since 1997. The wide oscillations in bottom biomass survey indices with time can be induced by changes on the adult redfish concentration near the bottom (fish grater than 30cm generally speaking), as well as on the distribution of this component in and out of the survey swept area of the Flemish Cap bank. Those changes are reflected on strong negative year effects on survey catchability through the full recruited age groups over the most recent years.

The 1989-2002 EU survey mean catch per tow for Div. 3M beaked redfish is also presented in Fig. 6b with the associated +/- 2 s.e.

During the former period of 1979-1985, covered by the Canadian surveys, female spawning biomass index of beaked redfish (SSB index) was stabilised and represented on average more than 40% of the survey bottom biomass (Table 2). Survey spawning biomass declined through the first years of EU survey series, staying at low level between 8,000-9,000 tons for most of the years since 1993. Over the more recent period the SSB index experienced large inter-annual variation, from a minimum in 1998 of 3,700 tons to 19,500 tons recorded in 2000, the highest value since 1990. In 2001-2002 the SSB index returned to 7,000-8,000 tons. From 1988 till 1991 female spawners represented between 22% and 28% of the bottom biomass index. Since 1994 this proportion has been oscillating between 9% and 12%, with the exception of 1998 (7%) and 2000 (18%) (Table 2, Fig. 6a).

On the Canadian survey series beaked redfish abundance index declined over the 1982-1985 interval. Although not comparable as absolute figures, abundance continues to decline in the EU survey series till 1990. The strongest year-class of the time series, the 1990-year-class, pushed the survey abundance to a maximum in 1992. Abundance declined sharply during the intermediate years, regardless the smaller peaks of 1994 and 1996. The second lowest abundance of the EU survey series is attained in 1998. Stock abundance increased continuously afterwards, despite the drop on biomass and spawning biomass in 2001. The pre-recruited age groups (1-4) have been supporting since 1999 this most recent increase on stock abundance. The 2000-year-class is the most abundant year-class at age 1 and the second largest at age 2 of the 1988-2002 interval (Table 6a).

Yield per recruit analysis

In order to get reference levels of fishing mortality taking into account the growth, maturity and exploitation pattern of the Div. 3M beaked redfish stock, an yield per recruit analysis was conducted incorporating the sets of vectors already described.

From the yield, biomass and spawning biomass per recruit curves, long-term spawning and total biomass per 1000 recruits were determined for different levels of fishing mortality (Table 8d, Fig. 6). With the assumption of constant recruitment, fishing at an $F_{0.1}$ of 0.08 will drive the long-term female spawning biomass to 34% of its unexploited size (= $F_{34\%SPR}$), representing by then 33% of the stock biomass. Fishing at $F_{0.1}$ will also stabilize stock biomass at 50% of its unexploited size. But the fishing mortality that will allow a long term female spawning biomass at 50% of its unexploited level (= $F_{34\%SPR}$), should be no greater than 0.06. This reduction corresponds to a proportion of female spawners in the stock biomass of 39%, a level near the average SSB proportion observed during the 1979-1985 Canadian series (42%). By that time, from the survey indices available, the stock was showing signs of stability while sustaining annual catches around 18 000 tons.

A precautionary level of fishing mortality based on Div. 3M *Sebastes mentella* growth

A growth based model (Beverton and Holt, from Die and Caddy, 1997) first applied on the 1998 assessment (Ávila de Melo *et al*., 1998) was updated in order to get a precautionary limit of Z, corresponding to a fishery where the mean length in the catch is above the mean length at maturity (Table 9). The F of 0.06 given by the Z "at maturity" assuming a natural mortality of 0.1, has the same magnitude of the (= $F_{50\%SPR}$), from the yield per recruit analysis associated with a long term 50% reduction on the female spawning stock biomass.

VPA based methods: the Extended Survivors Analysis option

The wide inter annual fluctuations of the Div. 3M beaked redfish survey abundance at age have been considered a strong handicap on the performance of VPA tuning methods such as the Extended Survivor Analysis (XSA) (Shepherd, 1999), due to its reflection on the high variability through ages, years and cohorts of the catchabilities that relate survey and/or commercial *CPUE's* with VPA abundance. Nevertheless the simple existence of the EU survey time series of abundance at age indices urged the authors to include for the first time an XSA in the Div. 3M beaked redfish assessment in 2000 (Ávila de Melo *et al*., 2000). The present Extended Survivor Analysis updates the 2002 XSA (Ávila de Melo *et al*., 2002), using the 1989-2002 EU survey abundance at age data as the tuning file.

The Separable Population Analysis (SPA) (Pope and Shepherd, 1982) has also been used in previous assessments (Ávila de Melo *et al*., 2000, 2001 and 2002). The purpose of this procedure was to check if the strong year/age effects on the XSA catchabilities have, or have not, a major impact on the perception of the recent history of this redfish resource given by other VPA based model (but free of a noisy survey tuning and just dependent of commercial catch at age). The results of this exercise had confirmed that, in the case of Div. 3M beaked redfish, biomass and fishing mortality outputs from survey and commercial input data used in XSA and SPA respectively are not in contradiction, regardless a better pattern of fitness to catch at age by the SPA model.

However he SPA/Cohort Analysis is a model dependent on an external guess (from the XSA results in this case study) of last year fishing mortality on the first fully recruited age (F_{Ty}) and on the selection for the last true age (S_{Ty}). Those input parameters are fixed previously and will drive the SPA fitting algorithm that will minimize the difference between the ratios of observed and expected catches. In other words SPA is not an autonomous model and should not replace a model such as XSA, with an independent tuning process for the objective computation of terminal fishing mortalities.

Basic assumptions

The input files for XSA analysis are presented in Table 10. Natural mortality was assumed constant at 0.1. The proportion of mature females at age is the one observed on the 1989-2002 period (Table 4c) and the month with a peak of spawning for Div. 3M *Sebastes mentella*, February (Saborido-Rey, 1994), was the one considered for the estimate of the proportion of F and M before spawning. The catch at age matrix includes the 1993-2002 by-catch at age from the shrimp fishery. The first age group considered was age 4 (the first age in the catch at age matrix with catches assigned every year) and age 18 was the last true age (from age 19 onwards both survey and commercial sampling data are scarce and so a plus group on age 19 has been considered).

Taking into account the relatively short time period available in contrast with a wider range of ages included in the assessment, and the slow progress on determinant processes for the stock dynamics such as recruitment, growth and female maturity, no year weights were used. The purpose is to give a full use and equal importance to the fourteen years of input data, namely the former ones till 1993 when a full-scale redfish fishery occurred on Flemish Cap. The use of year weights can be justified on long time series where there is a high probability that the exploitation pattern has not been kept constant. However it has the disadvantage of imposing the most recent exploitation pattern to the biomass estimate from earlier years of the time interval (Flatman, *pers. com.*, 1999). Anyway the shift observed during the nineties on the fishing mortality distribution through age as a consequence of the development and settlement of the Div. 3M shrimp fishery (Fig. 3) has not a major impact on the VPA based assessments: in fact, with the exception of 1993 and 1994, most of the catch from the first age group considered (age 4) came from the commercial round or flatfish fisheries rather than from by-catch of the Div. 3M shrimp fishery (Table 5).

The XSA program used was based in the algorithm implemented by Shepherd (1992) and is included in the Lowestoft VPA Suite (Darby and Flatman, 1994). The model algorithms are presented in Appendix 8 of the respective user guide (Darby and Flatman, 1994) and are summarized and adapted to this case study next.

The model

The XSA starts with the first estimates of abundance at the end of each terminal year for the last age of each cohort using the correspondent catch, the modified catch equation and an initial value of F (on oldest age each year and F at age in last year; see Table 10). If T_y and T_a are the terminal year and last age of a cohort, if $C_{(Ty,Ta)}$ is the correspondent catch and if $Pt_{(Ty,Ta)}$ are the survivors at the end of that year, the initial estimate of these survivors is given by the survivor equation:

$$Pt_{(Ty,Ta)} = N_{(Ty,Ta)} e^{-(F_{(Ty,Ta)}+M)} \qquad (1)$$

where $F_{(Ty,Ta)} =$ instant fishing mortality rate for the terminal year and the last age of a cohort,

$M =$ instant natural mortality rate (assumed to be constant through ages and years), and

$N_{(Ty,Ta)} =$ number of survivors reaching the last age of a cohort at the beginning of the terminal year, which in turn has a first estimate given by the modified catch equation

$$N_{(Ty,Ta)} = C_{(Ty,Ta)} (F_{(Ty,Ta)} + M) / F_{(Ty,Ta)} (1 - e^{-(F_{(Ty,Ta)}+M)}) \qquad (2)$$

The Cohort analysis model is then rearranged so that, for each age a and year y of each cohort the abundance is given by the survivors at the end of the terminal year of the cohort extended backwards, up till that age at the start of that year:

$$Nvpa_{(y,a)} = ECM_{(y,a)} Pt_{(Ty,Ta)} + Pc_{(y,a)} \qquad (3)$$

where

$$ECM_{(y,a)} Pt_{(Ty,Ta)} \qquad (4)$$

is the contribution of the raised accumulated natural deaths to the age a cohort abundance at the start of year y, from the terminal year Ty /last age Ta back to year y / age a, and

$$ECM_{(y,a)} = e^{[((Ty,Ta)-(y,a))+1)]M} \qquad (5a)$$

is the exponential cumulative natural mortality. The other term

$$Pc_{(y,a)} = \sum_{i=a,t=y}^{i=Ta,t=Ty} ECM_{(t,i)} C_{(t,i)} e^{-0.5M} \qquad (5b)$$

is the contribution of the raised accumulated catches to the age a cohort abundance at the start of year y, from the terminal year Ty /last age Ta back to year y /age a. The catch of each year t /age i within that interval is raised by the exponential cumulative natural mortality for the years/ages still missing to reach back the age a of the cohort at the start of year y

$$ECM_{(t,i)} = e^{[((t,i)-(y,a))+1]M} \qquad (5c)$$

Since catch at age and natural mortality are kept constant throughout the tuning process the term $Pc_{(y,a)}$ in equation (3) is constant as well.

The CPUE index U (in our case EU survey abundance at age) is first adjusted by an averaging factor (A) to the start of the year, in order to be directly related to population abundance. If catchability at age (q_a) is assumed constant with time:

$$U_{(y,a)} = q_{(a)} A_{(y,a)} N_{(y,a)} \qquad (6)$$

and

$$U'_{(y,a)} = \frac{U_{(y,a)}}{A_{(y,a)}} \qquad (7)$$

where

$$A_{(y,a)} = \frac{(e^{-\alpha(F_{(y,a)}+M)} - e^{-\beta(F_{(y,a)}+M)})}{(\beta-\alpha)(F_{(y,a)}+M)} \qquad (8)$$

and α and β are the start and end of the survey period. The survey estimate of population abundance at age a at the beginning of the year y, $Nest_{(y,a)}$, derived from the correspondent survey abundance at age adjusted to the beginning of the year, $U'_{(y,a)}$, could then be given by

$$Nest_{(y,a)} = \frac{U'_{(y,a)}}{q_{(a)}} \qquad (9)$$

For the younger ages in the assessment catchability at age, $q_{(a)}$, may be not only age dependent but may vary as well with the early strength of each incoming year-class. Under this hypothesis a power model (Shepherd, 1994) is used to calculate the survey catchability at age

$$U'_{(y,a)} = q_{(a)} Nvpa_{(y,a)}{}^{b} \qquad (10)$$

through its linear regression

$$LnNvpa_{(y,a)} = \frac{1}{b} LnU'_{(y,a)} - \frac{Lnq_{(a)}}{b} \qquad (11a)$$

when $b \neq 1$. For each pair of $Lnq_{(a)}$ and b fitted on each iteration, the *log* linear equation (11) will be used to predict a survey estimate of population at age a at the start of year y, $Nest_{(y,a)}$, from the EU survey abundance at age a corrected to the start to the year y, $U'_{(y,a)}$.

For ages with catchability not dependent of year-class strength $b = 1$. The catchability at age, $q_{(a)}$, will be given by the log fit of the $(Nvpa_{(y,a)}, U'_{(y,a)})$ pairs to the linear model

$$LnNvpa_{(y,a)} = LnU'_{(y,a)} - Lnq_{(a)} \qquad (11b)$$

and $Nest_{(y,a)}$ by equation (9). In the Div. 3M beaked redfish assessment, catchability of the recruiting ages will not vary with the year-class strength (the background for this assumption will be explained later on). So, the equations presented onwards are only the ones related with an age dependent catchability, constant at each age over the time interval.

The catchabilities for each age are calculated by the program through the *log* reciprocal catchability, given by the mean of the time series values:

$$Ln\left[\frac{1}{q_{(a)}}\right] = \frac{\sum_{y=1st}^{Ty}\left[Ln(Nvpa_{(y,a)}) - Ln(U'_{(y,a)})\right]}{n_{(a)}} \qquad (12)$$

For those ages with constant catchability the standard error of each $Nest_{(y,a)}$ is given by the standard error of the *log* reciprocal catchability at each age and, since catchability is constant with time this standard error will be kept constant for all years:

$$\sigma(a) = \sqrt{\frac{\sum_y \left[Ln\left[\frac{Nvpa_{(y,a)}}{U'_{(y,a)}}\right] - Ln\left[\frac{1}{q_{(a)}}\right]\right]^2}{n_{(a)} - 1}}\sqrt{1 + \frac{1}{n_{(a)}}} \qquad (13)$$

After all cohort's $Nest_{(y,a)}$ and associated standard errors are estimated, the terminal population of the cohort is then given by a weighted mean of each terminal cohort estimate at the end of the terminal year, given by the forward estimated abundance from each age of the cohort

$$LnPt_{(Ty,Ta)} = \frac{\sum_{i=Fa}^{i=Ta}\left[w'_{(y,i)}\,(LnNest_{(y,i)} - LnECZ_{(y,i)})\right]}{\sum_{i=Fa}^{i=Ta}\left[w'_{(y,i)}\right]} \qquad (14)$$

where

$$w'_{(y,i)} = \frac{1}{\sigma^2_{(i)} ECF_{(y,i)}} \qquad (15),$$

Fa is the first age of the cohort,

$$ECZ_{(y,i)} = e^{(M+F_{(y,i)})+(M+F_{(y+1,i+1)})+...+(M+F_{(Ty,Ti)})} \qquad (16) \text{ and}$$

$$ECF_{(y,i)} = e^{F_{(y,i)}+F_{(y+1,i+1)}+...+F_{(Ty,Ti)}} \qquad (17)$$

are the exponential cumulative total and fishing mortalities from each age i until Ta, and $\sigma^2_{(i)}$ is the variance of each $Nest_{(y,i)}$ value.

This cohort's terminal population will then initialise the next iteration. The exponential cumulative fishing mortality enters in the weighting process of the mean terminal population as a second weighting factor that will reduce the influence of the terminal estimates from the younger ages of the cohort.

The internal standard error of the cohort terminal population is given by the standard errors of the $Nest_{(y,a)}$ that contributed (with a terminal estimate from each age) to its calculation:

$$\sigma\, int(Ty,Ta)^2 = \frac{\sum_{i=Fa}^{i=Ta}\left(\frac{1}{\sigma^2{}_{(i)}ECF_{(y,i)}{}^2}\right)}{\left(\sum_{i=Fa}^{i=Ta}\frac{1}{\sigma^2{}_{(i)}ECF(y,i)}\right)^2} \qquad (18)$$

The external standard error of the cohort terminal population is given by the standard error of the terminal estimates, $Ptest_{(y,a)}$, obtained from each cohort age

$$\sigma ext(Ty,Ta) = \sqrt{\frac{1}{n-1}}\sqrt{\frac{\sum_{i=Fa}^{i=Ta} w'_{(y,i)}\left[Ptest_{(y,i)} - Pt(Ty,Ta)\right]^2}{\sum_{i=Fa}^{i=Ta} w'_{(y,i)}}} \qquad (19)$$

where

$$Ptest_{(y,a)} = LnNest_{(y,a)} - LnECZ_{(y,a)} \qquad (20)$$

and $w'_{(y,i)}$ are the weighting factors used in the computation of the terminal population mean $Pt_{(Ty,Ta)}$. The XSA run ends when

$$\sum_a \left|(F_{(a,Ty,i)} - F_{(a,Ty,i-1)}\right| < 0.0001$$

in other words, when the sum of absolute fishing mortality residuals for all ages *a* in the terminal year Ty , between iteration i and the previous one, is less than 0.0001.

The framework

As justified earlier no tapered time weighting was applied. Final fishing mortality estimates were not shrunken towards a mean F either, taking into account the sharp declining trend of fishing mortality over the second half of the nineties and the likely (small) increase of F on recent years, following the higher level of catches in 2000-2002. Under these circumstances the shrinkage will flat the changes occurring on F , masking its impact on the present stock status.

A first run with catchability dependent of year-class strength on all ages till the penultimate true age (17) showed all ages with high regression standard errors, most of them with high *t* values of the slope as well. However the regression statistics of catchability for the younger ages considered (4 and 5) present *t* values of the slopes, that linearly relate the log abundance at age with the log survey index at age adjusted to the start of the year, not differing significantly from 1 (*Student's t* test with 12 degrees of freedom = No. points – 2, significance level of 0.05). This lack of a significant trend on the younger ages regression slopes led us to treat the catchability independent with respect to year-class strength and time through all the age spectrum of the assessment (Darby, *pers. com.*, 2000).

During the 2001 assessment four exploratory runs were performed to select an age for fixing catchability and choose a minimum standard error for the log catchability of the last true age, in order to avoid overweight of the cohort's terminal population estimates by the last true age. Taking into account that catchability declines on older ages, the results of this exercise pointed out that fixing catchability only since age 17 (not shrinking the range of true ages involved on the assessment of a long living stock) and keeping the minimum standard error of the *log* catchability of age 18 at 0.5 (instead of adopting a lower minimum) improved the fitness of the model to the existing data. The present assessment uses the previous XSA framework: no recruiting ages with catchability dependent of year-class strength, constant catchability just at the penultimate age and a minimum standard error of the *log* catchability for the lat true age of 0.5.

Diagnostics

The diagnostics of the 2003 XSA are presented on Table 11 and Fig. 8a,b. Extended Survivor Analysis converged after a high number of iterations, showing a high variability on survey catchability at age (Table 11/ Mean *log* catchability and standard errors for ages with catchability independent of year-class strength and constant w.r.t. time) and a clear pattern of year effects (Table 11/*log* catchability residuals; Fig. 8a). Most of the *log* catchability residuals were positive during the intermediate years of 1994 to 1997, while on the former years till 1991 and again on 1998 and 2001-2002 most ages had negative residuals.

The diagnostics present very high negative *log* catchability residuals on younger ages 4 to 6 on the former years of 1989 and 1990 (Table 11/*log* catchability residuals; Fig. 8a). Nevertheless, from the moving average of the sum of squares of the *log* catchability residuals (4 year intervals) it can be inferred that the size of *log* catchability residuals over the most recent years (1999-2002) is smaller than through the preceding years (Fig. 8b).

Low fishing mortalities from 1997 onwards, well bellow the assumed level of natural mortality, temporal changes on beaked redfish concentration near the bottom of the survey swept area (amplifying the noise on the *log* catchabilities at age and introducing strong year effects) together with a declining trend of catchabilty with age (Table 11: regression statistics/mean Q), contributed to the long process of convergence.

A 2002-2000 retrospective analysis was carried out in order to compare the patterns on the biomass, female spawning stock biomass (SSB), fishing mortality (average F: ages 6-16) and recruitment (age 4) estimates, from consecutive assessments back in time. This retrospective analysis was confined to the most recent years preserving at the maximum extent the life span of the cohorts occurring from 1989 onwards, namely the 1990-year-class. The use of just the last assessments avoids the premature truncation of the (long living) cohorts that are the bulk of the present exploitable stock.

The retrospective XSA present an over bias pattern on biomasses and an under bias pattern on fishing mortality (Table 11b and Fig. 9abc). The last three assessments present close estimates of both fishing mortality and female SSB until 1996 and 1998 respectively. Fishing mortality drops to very low levels from 1997 onwards and so the relative size of the discrepancies increased since then. The 2003 XSA estimates for 2001 biomass, female SSB and fishing mortality are around +/- 20% of the correspondent 2002 assessment results. From the possible causes of retrospective patterns – patterns of misreporting, patterns in catchability or misspecification of natural mortality (Sinclair *et al*., 1990) – the year patterns in catchability, translated in high positive or negative *log* catchability residuals through most of the ages on several years, can be the main cause of bias in a redfish assessment. In long living stocks, with a large number of ages and survivors at the end of the terminal year included in the assessment, the patterns in catchability can be reflected on the patterns of the retrospective size of survivors and of their cohorts size, extended till recruitment. For the 2000-2002 assessments, where all the recruitments are estimated from the respective survivors, an over bias of the 1990-1995 cohorts at age 4 shows up in the retrospective analysis (first age group of the XSA's, years 1994-2000; Table 11b and Fig. 9d). For weak year-classes the impact of such recruitment over bias, first on biomass and later on female SSB over bias, can be neglected. But recruitment over bias of a strong year-class will be foreseen. Namely if such a strong year-class is driving the biomass and SSB trends of a stock just leaving overexploitation with most of its cohorts depleted and/or weak, as it is the case of Div. 3M beaked redfish.

In summary, the poor fit of the XSA model to the survey abundance at age seems related both with redfish own biology and recent low levels of fishing mortality below natural mortality. This poor fit is a burden any redfish / lightly exploited stock assessment has to carry when using VPA based models supported by survey tuning. Despite the long process of convergence, the year patterns in the residuals of cachability at age as well as the SSB and fishing mortality patterns of the retrospective analysis, the 2003 XSA results are not only consistent for the majority of years within the overlap assessment interval of the more recent XSA's but should also be regarded as the closest picture one can get of the actual Div. 3M beaked redfish stock size.

Results

The Extended Survivor results are presented on Table 12 and Fig. 10abcd.

Very high fishing mortalities until 1996 (more than doubling the assumed natural mortality) forced a rapid and steep decline of abundance, biomass and female spawning biomass of the Div. 3M beaked redfish stock (Fig.

10a and b). From 1997 onwards, low fishing mortalities allowed a discontinuous and slow growth of both biomass and SSB but abundance was kept stable at a low level from 1996 to 2001, only increasing in 2002 with the income of the above average 1998 year-class to the 4+ stock (Table12/ Table 10 stock number at age (start of the year)). An unexpected (and isolated) drop on female SSB and stock biomass is observed in 1999. The sharp decline observed between 1997 and 1998 of the survey catchabilities for most of the cohorts (Table 11b/*log* catchability residuals; Fig. 16) could be reflected on the 1998 fishing mortalities for those same cohorts, probably over-estimated by the XSA and leading to an unrealistic depressed stock at age at the beginning of 1999.

There was a general increase of the stock reproductive potential from 1992 to 1998 (Fig. 10c). However in 2002 female spawning stock biomass was still far away from a SSB level of 80,000 tons, beyond which two consecutive above average recruitments were observed in 1989 and 1990 (Fig. 10b and d). At the same time the appearance of the first abundant year-class after 1990, the 1998 cohort, may suggest that above average recruitments can be expected at much lower SSB levels but this signal needs to be confirmed in future assessments. All points in the reproductive potential and SR plots are comparable since all year-classes included had already passed through the shrimp fishery during their early life stage, and so all of them have been depressed by the by-catch mortality over the pre-recruited ages.

A Non-equilibrium stock production model incorporating covariates (ASPIC)

The ASPIC model (Prager, 1994, 1995) fits a non-equilibrium logistic production model to several yield and/or biomass series such as catch and effort, catch and *CPUE*, survey biomass indices and independent biomass estimates.

Basic assumptions

Being K the carrying capacity stock biomass, r the intrinsic rate of stock biomass increase, C the catch biomass, MSY and $Bmsy$ the long term yield and biomass associated with $Fmsy$, the same being applied to $Y_{0.1}$ and $B_{0.1}$ as regards $F_{0.1}$, the model basic assumptions are:

1) A logistic population growth over time of the unexploited stock (Schaefer, 1954)

$$dB_t / dt = rB_t - (r/K)B_t^{\,2} \qquad (1)$$

2) For an exploited stock catch is also incorporated in the population growth

$$dB_t / dt = rB_t - (r/K)B_t^{\,2} - C_t \qquad (2)$$

3) The biological reference points are (Schaefer, 1954)

a. $MSY = rK/4$ and $Y_{0.1} = 0.99Ymsy$ (3)

b. $Bmsy = K/2$ and $B_{0.1} = 1.10Bmsy$ (4)

c. $Fmsy = r/2$ and $F_{0.1} = 0.9Fmsy$ (5)

The model assumes that for each data series q, the catchability that relates each year fishing mortality (F_t) with correspondent fishing effort (f_t), or the ratio between a biomass index and the stock biomass, is constant over time.

The model

Assuming catch (yield, Y) as exact and accumulating residuals in effort, having user defined starting guesses for r, MSY, K and $B1$ (stock biomass on the first year of the time series, expressed in the program output as a ratio to $Bmsy$), a program starting guess for the *CPUE* catchability (q_0) and a fixed user defined value for survey catchability (q_{survey}), ASPIC uses the catch and *CPUE* series in order to generate initial and average biomass estimates (at the beginning and middle of each year), going through an estimation procedure that is summarised next (Praguer, 1994; Azevedo, *pers. comm.* 1999):

1) Using the starting guesses r_0, q_0, K_0 and B_0, estimate effort f for the first year ($t = 1959$) by solving iteratively

$$\hat{F}_t = \frac{\frac{r_0}{K_0} Y_t}{Ln\left[\frac{\frac{r_0}{K_0} B_0 e^{(r_0 - \tilde{F}_t) - 1}}{(r_0 - \tilde{F}_t)} + 1\right]} \quad (6)$$

with a starting guess for fishing mortality of $\tilde{F}_t = Y_t / B_0$ and seeking for convergence. Once fit $\hat{F}_t$ than the expected effort is computed as $\hat{f}_t = \hat{F}_t / q_0$ (7) (the observed effort f_t is given by the catch/*CPUE* ratio).

2) Than estimate the biomass for the next year by solving

$$B_{t+1} = \frac{(r_0 - \hat{F}_t)\hat{B}_t e^{(r_0 - \hat{F}_t)}}{(r_0 - \hat{F}_t) + (\frac{r_0}{K_0})\hat{B}_t (e^{-(r_0 - \hat{F}_t)} - 1)} \quad (8)$$

and compute $\hat{F}_{t+1}$ and $\hat{f}_{t+1}$ and f_{t+1} using equations (6) and (7).

3) The estimated average biomass for year t+1 will be given by

$$\hat{B}_{t+1average} = Y_{t+1} / \hat{F}_{t+1} \quad (9) \quad \text{or} \quad (\hat{B}_{t+1} + \hat{B}_t)/2 \quad (10)$$

4) Using the input survey catchability q_{surv} the average biomass for year t+1 (the EU survey is carried out at the middle of the year) is transformed in the corresponding estimated survey biomass

$$\hat{B}_{t+1survey} = q_{survey} B_{t+1averagesurvey} \ (11), \text{ where } B_{t+1averagesurvey} = (B_{t+1survey} + B_{tsurvey})/2 \ (12)$$

5) The process is repeated for each year in the analysis.

4) The objective function is computed as the sum of the sums of log squared residuals between the observed and expected effort and between the observed and expected survey biomass

$$Obj.function = \sum_{t=1959}^{T=1993} \left[Ln(f_t) - Ln(\hat{f}_t)\right]^2 + \sum_{t=1988}^{T=2002} \left[Ln(B_{tsurvey}) - Ln(\hat{B}_{tsurvey})\right]^2 \quad (13)$$

This routine is repeated until the objective function is minimized.

ASPIC run first on the FIT mode to have the deterministic parameters estimate, together with effort and survey pattern of un-weighted residuals, as well as biomass and fishing mortality trends (expressed as ratios to $Bmsy$ and $Fmsy$). On the bootstrap procedure (BOT mode) effort and survey residuals were re-sampled 1000 times in order to derive bias corrected estimates and probability distribution of the parameters. The program uses bias corrections based on medians (Mainly, 1997) and so, being P the fit estimate of a parameter and P_m its median value from the bootstrap, then the bias corrected estimate P_{bc} will be given as

$$P_{bc} = P - (P_m - P) \qquad (14)$$

The framework

The model requires from the user a set of inputs (Prager, 1995), which were updated from previous assessments (Ávila de Melo *et al*., 2000-2002) and are defined as follows (Table 13a):

1) Maximum F when estimating effort. From the XSA the maximum level of the mean fishing mortality was 0.5. In the ASPIC runs the maximum F was set 3 times higher than this level, at 1.5.

2) Penalty term for $B1$ (stock biomass at the first year of the time series) greater than K. The model fitted successfully without a penalty term.

3) Data series. On the 1999 assessment the inclusion, in a first exploratory ASPIC run, of all *CPUE* and survey series available for Div. 3M beaked redfish (Canadian, Russian and EU survey bottom biomass as well as the STATLANT and Portuguese *CPUE* series) resulted in negative or very low correlations between most of them (Ávila de Melo *et al*., 1999). The STATLANT commercial *CPUE*, built with STATLANT catch and effort data for most of the components of the fishery from 1959 to 1993 (Gorchinsky and Power, 1994), is considered to be the backbone of the ASPIC assessment due to its extension. This commercial *CPUE* series runs with the EU bottom biomass (1988-2002), recalculated as a sum of products corresponding to the age 4 plus biomass. These two series have the highest correlation between any possible combinations of the series available for this resource.

4) No series specific statistical weights were given.

5) The MSY was set at 20,000 tons as a starting guess corresponding to the upper level of catches during the former period of relative stability of this stock between the late seventies and the first half of the eighties, as pointed out by the Canadian survey series. Nevertheless, taking into account the recent history of the Div. 3M redfish fishery, MSY was allowed to vary between 10,000 tons and 50,000 tons.

6) The starting guess for r was 0.16. This value is the double of the $F_{0.1}$ given by the yield per recruit analysis, which is supposed to stabilize stock biomass at 50% of its unexploited size (Table 8d). This means that $F_{0.1}$ can be accepted as a proxy of F_{msy} of the Schaefer production model. Due to the slow growing and long living features of redfish species the lower limit for r was set at 0.05, but allowed to vary up to 1.0.

7) The starting guess for EU survey catchability (the ratio between survey biomass and stock biomass) was set at 0.657. This value corresponds to the geometric mean of the survey bottom biomass/XSA stock biomass ratio for the whole 1998-2002 interval of overlap between the two biomass series. A geometric mean of the whole interval is justified due to a better goodness-of –fit of the survey series to the surplus production model. Survey catchability was the only parameter that was fixed, since when the model is allowed to do this estimate by its own the run does not end normally, generating an unrealistically low catchability and extremely high biomass estimates, which are kept almost undisturbed over large periods of time.

Diagnostics

The ASPIC output is presented in Table 13b in the standard format delivered by the program. The first five pages of this table have the diagnostics and results from the non-bootstrapped analysis, while a summary of the bootstrap analysis is on the last page. Despite the low correlation of either survey biomass and *CPUE* series with the biomass fitted by the ASPIC model (Table 13b, page 1, see GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS, R-squared in CPUE) and the strong log residual patterns for both data series (Table 13b, page 4, see UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 1=EU survey; Table 13b, page 6, see UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 2=STATLANT CPUE), in general there is a small difference between the bias-corrected and ordinary estimates (0.2%-3.6%) indicating for most of the parameters a distribution close to normality.

Results

The production model estimates a stock biomass 65% above $Bmsy$ till the early seventies. A first drop of stock biomass occurred between 1973 and 1975: by then stock biomass was already not higher than 42% above $Bmsy$. Biomass slowly declined afterwards to 32% above $Bmsy$ in 1985, while supporting catches between 14,000 tons and 20,000 tons. Stock biomass continues to decline during the second half of the eighties but at a faster rate and by 1990 the $Bmsy$ level was already left behind. An historic stock biomass minimum 35% bellow $Bmsy$ was finally reached in 1996. Meanwhile fishing mortality was at or well above $Fmsy$ between 1986 and 1995, inducing a stock decline that went faster through the first half of the nineties (Fig. 11a). Low fishing mortalities 1997 onwards gave room to slow stock recovery, with biomass at beginning of 2003 representing 62% of the $Bmsy$. Fishing mortality recorded a moderate increase in 2000-2002 but within a level well bellow $Fmsy$ (35%) (Table 13b, page2, see ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)). The ASPIC corrected estimate for $Fmsy$ is 0.066, with an inter quartile range for 50% confidence limits of 0.032. This is a fishing mortality level lower than $F_{0.1}$ (0.082) and similar to $F_{50\%SPR}$ (0.060), with an upper limit at the assumed natural mortality (0.1). As for MSY the ASPIC bias corrected estimate is of 16,800tons with an inter quartile range for 50% confidence limits of 3,600tons (Table 13b, page 6, see RESULTS OF BOOTSTRAPPED ANALYSIS).

The ASPIC biomass follows the same pattern of the previous XSA assessment, though with closer estimates to XSA biomass over the former years till 1998. From 1993 onwards the 4+ EU survey biomass is the only time series available to adjust to the production model and over the 1993-1998 period ASPIC and XSA biomass have a reasonable good match. But on the final years of the time series the production model is not sensitive to the survey biomass fluctuations and with low fishing mortalities and a constant rate of increase ASPIC biomass grows faster than XSA biomass between 1999 and 2002(Table 14, Fig. 11).

Status of the Div. 3M beaked redfish stock

Either XSA or ASPIC analysis pointed out that the Div. 3M beaked redfish stock experienced a steep decline from the second half of the eighties till 1996. Fishing mortality was kept well above F_{msy} over the first half of the assessment period, due to increasing commercial catches since the mid eighties that reached a top level within 1989 and 1993. From 1995 onwards fishing mortality dropped and since 1997 has been kept well below natural mortality, allowing the survival and growth of the remainders from all cohorts. But the 1993-1994 high by-catches in numbers at age 4 depressed the most abundant cohorts at that time (1989 and 1990), reducing their potential contribution on fastening the recovery of biomass and female spawning biomass. Despite recent fluctuations biomass is generally increasing since 1997 but slowly, being still well bellow the level estimated for the beginning of the time series (1989). The same irregular and discrete pattern of growth is observed on the female spawning biomass, also recovering from the 1996 minimum. Female survivors from the abundant 1990-year-class and from younger cohorts, progressively reaching maturity over recent years, support this recovery of female spawning biomass. The prospective of a no return increase of both biomass and SSB seems to consolidate under the present low exploitation regime: the stock reproductive potential has increased through the nineties (Fig. 10c) compensating the SSB decline and sustaining a 1998-2002 geo-mean recruitment at age 4 identical to the former years of 1989-1993 (around 55 million fish). The 1998 year-class, recruiting in 2002, is 173% above the 1989-2002 geo-mean recruitment (including both 1989 and 1990 above average year-classes). However an SSB approaching 80,000tons (a target lower limit of the female spawning stock biomass, above which two of the three most abundant cohorts were produced; Fig. 10d) will not be foreseen in the next coming years, even keeping the actual low level of exploitation and assuring a high rate of survival not only of the promising 1998 year-class but also of the recent 2000 year-class (the most abundant year-class at age 1 and the second largest at age 2 of the 1988-2002 interval, from EU survey results).

By-catch mortality continued to act as a buffer on survival of pre-recruits and its impact increases with year-class strength, as its is illustrated in the 2001-2002 length composition of redfish by-catch (Table 1b and c; Fig. 2b). The actual sorting grades are ineffective to avoid large amounts of by-catch of redfish of small sizes up to 14cm. In 2002 this small redfish Div. 3M shrimp by-catch represented 56% of the Div. 3M redfish total catch in numbers (Table 2c), with the 1999-2001 year-classes forming the bulk of the catch (Table 5, Fig. 3). With the availability of the above average abundance of the 2000 year-class to shrimp trawlers there is little doubt that a faster rate of stock growth, both in biomass and namely in abundance, is now dependent on the survival of this abundant cohort through its early life stage preceding recruitment to commercial fishery. Keeping catch and fishing mortality at a low level can only be effective in supporting a medium term faster stock recovery if measures to drastically reduce by-catch of very small redfish are implemented in the short term.

Short and medium-term projections

The likelihood of the spawning stock biomass and yield trajectories under a certain level of fishing mortality was given by a medium-term projection program (Mterm) running with the bootstrap of recruitment (from a chosen Stock/Recruitment function) and with the initial population at age abide to a measure of uncertainty. This program of the CEFAS laboratory (Lowestoft/UK) was applied in a NAFO stock for the first time in 2000 (Mahe and Darby, 2000). The program has been upgraded recently to allow projections for long living stocks with a large number of ages included in the analytical assessment (Smith and Darby, *pers. comm.* 2001). The input data are aggregated in two categories of files:

a. Two *red.srr* (stock recruitment relationship) files (Table 15ab), both adopting as the Div. 3M redfish SRR model a random recruitment around the geo-mean of the 1999-2001 recruitments, but each file assuming a different stock productivity scenario for the near future. In one file (*srrlow*) the first age at the beginning of each year within a Mterm projection is given by the re-sampling of the residuals of the 1989-2001 XSA *log* recruitments from the *log* 1999-2001 geo-mean, with the strong 1989 and 1990 year-classes at the beginning of 1993 and 1994 substituted by the geo-mean of the recruitment of the adjacent years of 1992 and 1995, and the above average recruitment of the 1998 year-class at age 4 in 2002 ignored. This means that the projections with this *srrlow* file are assuming for the next coming years a zero probability of peaks in recruitment at age 4 similar of the ones observed in 1989, 1990 and 1998. This is a rather conservative scenario namely if the early survey strength of the 2000 year-class is also confirmed on the next coming years. The other file (*srrobs*) incorporates all *log* recruitment residuals for the whole assessment period, 1989-2002, including the ones from the above average cohorts. Details as regards the inputs of the two *red.srr* files are included in each file as text comments.

b. A *red.sen* (sensitivity) file including the usual vectors needed to forward projections but with uncertainty associated to the population at age at the beginning of the first year of the projection (Table 26). The XSA survivors at age by the end of 2002, plus a recruitment given by the bootsrap of the residuals stored in one of the two *red.srrr* files, are the starting population at age at the beginning of 2002. Being the internal and external standard errors from XSA diagnostics (Table 11a/ Terminal year survivor and F estimates) two measures of the uncertainty around the survivor estimate for each age, their average was adopted as the coefficients of variation associated with the starting population at age. These CV's ranged from 18% (age 17) to 47% (ages 4-6) and were used to bootstrap the initial population at age for each Mterm projection.

A single short-term *status quo* catch option was chosen from 50th probability catch profiles of several exploratory Mterm stock projections, driven by several fishing mortalities picked up from a range of 30% to 100% $F_{statusquo}$ $(= Fbar_{2002}$, average fishing mortality for ages 6 to 16). Each projection (computed from 1,000 trials) was made with an F at age distribution corresponding to a certain proportion of $F_{statusquo}$ (the *exploitation pattern* *for human consumption* of the *red.sen* file) and with each of the stock productivity scenarios. From those exploratory Mterm runs the chosen option of fishing mortality corresponds to short term catches within an interval defined by the recent level of total catch (including by-catch) of 4,000 tons and the actual TAC of 5,000 tons. Such option is given by 40% $F_{statusquo}$ regardless the adopted productivity regime.

The results are presented as 5, 10, 25, 50 and 95 probability profiles for:

a. Short-term (beginning of 2005) female spawning biomass projections for a range of F bar's. The middle of this range corresponds to 40% $F_{statuquo}$ (Table 16a and Fig. 12ab).

b. Medium-term (beginning of 2012) female spawning biomass projections for a range of multipliers of 40% $F_{statuquo}$ (Table 16b and Fig. 13ab).

c. 2003-2012 spawning biomass trajectories keeping fishing mortality at 40% $F_{statuquo}$ (Table 17a and Fig. 14ab).

d. 2003-2012 yield trajectories keeping fishing mortality at 40% of $F_{statuquo}$ (Table 17b and Fig. 15ab).

A 40% reduction on $F_{statuquo}$ will keep, for most of the present decade, catches anchored between their present level and the adopted 2000-2003 TAC, but at the same time will allow, with a high probability (20^{th} % probability profile) a 50% increase of the actual female spawning stock biomass by 2006 and a 2011 SSB representing at least 80% of the female SSB level estimated for the start of the time series. The Mterm results also suggest that the impact on biomass and catch of either productivity scenarios is null on the short term. However within the next ten years the same fishing mortality regime will drive female SSB closer to a safe level of 80,000 tons if similar pulses of recruitment continue to occur in the near future and are allowed to reach age 4 still as strong year-classes. At the same time, and at the same level of fishing mortality, catches will have more room to gradually increase from 2009 onwards if recruitment follows the observed productivity pattern of the last 14 years (Table 18, Fig. 16ab).

Even associated with uncertainty any projection should be taken with caution. The similarity between short-term projections from consecutive years depends not only on the similarity between the near future and the recent past as regards recruitment, but also on a consistent estimate of the population at the first common year of two consecutive projections. This consistency depends on how close is the estimate of survivors at age by the end of the terminal year of the previous assessment (initial population of last year projection) to the new estimate of the same individuals, now calculated by the XSA as the population at age at the beginning of the terminal year of the actual assessment (from which the survivors that initialise this year projection are calculated). These concerns are well illustrated in the comparison of the Mterm 50^{th} ile trajectories starting at 2002 (under 60% $Fbar_{2001}$) and at 2003 (under 40% $Fbar_{2002}$), both projections with catches until 2006 between the actual level of total catches and the TAC of 5,000 tons (Table 19, Fig. 17ab) and assuming the same low productivity regime as regards recruitment at age 4 for the next coming years.

The difference between the 2002 mature female population at age as survivors by the end of 2001, that was used to start the 2002 Mterm projection, and the same 2002 mature female population at age now calculated by the 2003 XSA as the population at the beginning of 2002, will contribute to apart the trajectories from the two projections: a lower magnitude for the 2003 starting population (2002 survivors) when compared with the one predicted by the 2002 Mterm projection, and a lower SSB trajectory that will tend anyway to approach the previous one with time(Fig. 17a) . Discrepancies are not so obvious within the yield trajectories that entangle one to the other through most of the next coming years, only starting to divert from 2009 onwards (Fig. 17b).

The underlying assumption of these 2002-2011 and 2003-2012 projections, that no pulse of recruitment will be foreseen in the next coming years, can fall with the appearance of one or two year-classes strong enough to be still well above average when reaching age 4. That can very well be the case of the 1998 and 2000 year-classes. But even so a faster biomass growth rate would not put the stock at a safe SSB level within a shorter period of time, due to redfish slow growth and long maturation process. Further increase of the stock and spawning biomass will continue so far to be dependent on keeping fishing mortality at a low level, below both the assumed natural mortality and $F_{0.1}$. At the present stock size and taking into account the trajectories of the last Mterm projections, this should correspond to a level of catch not higher than 5,000 tons until the end of the present decade regardless the recruitment regime that will prevail on the near future.

Acknowledgements

This assessment is part of a EU research project supported by the European Commission (DG XIV, Program for the collection of data in fisheries sector), IPIMAR, CSIC, IEO and AZTI. The authors would like to thank Dave Kulka (DFO/Science Branch, Canada) and Alexander Vaskov (PINRO, Russia) for the early submission of 2002 length data on by-catch and commercial catch from their countries.

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Table 1a: 3M Redfish nominal catches by country, 1985-2002.

Country	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000 (a)	2001 (a)	2002 (a)
CAN							2		10			2				5		
CUB	1831	1764	1757	1759	1765	4195	1772	2303	945									
DDR		88				4025												
GRL								1		26								
JPN	313	400	131	393	885	2082	1432	1424	967	488	553	678	212	440	321	31	80	67
SUN/RUS	15703	15045	19875	13747	13937	34581	24661	2937	2035	2980	3560	52		25	92	1808	1292	1155
LVA								7441	5099	94	304							
LTU									2128								10	10
EST										47						632	167	5
E PRT	1306	10783	21823	7101	13012	11665	3787	3198	4781	5630	1282	332	83	259	96	916	1589	1512
EU	2435	11571	22648	7247	13225	13672	10111	6845	4881	6240	1282	332	335	455	505	1349	1746	2011
KOR-S		5		43	17885	8332	2936	8350	2962									
FAROE IS.								16										0.1
NORWAY										8	3							
Total	20282	28873	44411	23189	47697	66887	40914	29317	19027	9883	5702	1064	547	920	918	**3825**	**3295**	**3248**

(a) NAFO circular letters with monthly provisional catches, 2000-2003

STCAFIS Estimates of commercial catches from various sources. Catches used in the assessment in bold.

Total	**20282**	**28873**	**44411**	**23189**	**58100**	**81000**	**48500**	**43300**	**29000**	**11300**	**13500**	**5789**	**1300**	**971**	**1068**	3658	3224	2934

Table 1b: Length composition (absolute frequencies in'000s) of the 3M redfish commercial catch, 1989-202.

Length	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
10	3				1									1
11														
12	3				1							9		1
13	12				9	1						17		1
14	29	4			117	12						1		2
15	9	81			395	44				2		9	4	4
16	34	211			440	132		22				1	4	10
17	69	808			167	391		22	1	2		9	22	24
18	34	2787	175		101	843	129	22		1		26	62	49
19	12	6470	726	70	130	1030	291	74	7	9	1	40	45	97
20	128	6925	1494	352	145	501	1273	400	8	14	2	68	46	160
21	440	3253	1385	1856	327	515	3222	1073	16	31	1	52	68	166
22	1316	1344	1323	3110	970	598	6630	2464	44	57	2	120	126	164
23	4317	2146	1060	2376	1894	732	6431	1825	112	104	1	121	213	187
24	9628	6157	1904	1469	3372	1408	1901	1472	284	128	10	244	300	318
25	16884	13302	4193	2760	3160	1999	1282	872	351	246	122	348	490	483
26	16970	22298	7061	8656	3345	2005	858	569	335	247	116	732	969	605
27	12796	28705	11632	13299	3277	1782	1028	822	213	229	228	1278	1345	811
28	8096	29130	14411	13405	4024	2439	1276	842	183	191	317	1604	1570	1037
29	6605	22485	16923	9609	3530	2587	1588	951	227	185	319	1397	1291	1040
30	8465	16982	14634	8119	5261	2783	1621	998	267	178	210	957	1078	1007
31	7949	11308	8359	5797	4611	2526	1356	1058	240	188	218	662	582	788
32	8432	9266	7907	5124	3629	2196	1405	985	268	172	255	465	368	589
33	8022	7303	3946	4535	3748	1456	1312	761	290	123	185	357	229	481
34	7899	7133	4361	4771	3079	931	1084	742	115	81	89	322	160	290
35	7432	6115	3477	4814	3308	994	1113	310	82	59	150	203	84	143
36	5607	4900	2938	3476	2903	623	1121	218	46	51	81	160	42	93
37	4655	3394	2683	2604	2777	354	985	244	26	50	71	151	34	29
38	2786	2458	1874	1733	1536	303	805	114	29	36	9	128	40	24
39	1787	1734	1959	1388	1318	152	525	139	12	32	31	54	18	18
40	1082	856	1148	974	695	100	504	50	4	17	2	35	11	9
41	577	647	717	583	392	78	372	42	13	12	5	24	5	2
42	390	384	225	233	339	26	176	50	6	9	1	16	7	2
43	332	294	317	274	149	15	74	20	1	3	2	22	3	6
44	155	145	22	199	443	26	54	3	7	2		15	2	
45	163	81	16	45	55	16	37	2	1		2	3	1	
46	85	36	9	10	45		8	4	1	1		7	1	
47	53	18			36		20	1	1			4		
48	32	13	9	20	65		5						1	
49	4	13												
50	12	4						30						
51	4	13												
52	4													
53	8	18												
54		9												
55		4												
56														
57														
58		4												
59														
60														
61									12					
no ('000)	143320	219243	116888	101663	61265	29599	38484	17202	3202	2461	2429	9662	9220	8643
weight (tons)	**58100**	**81000**	**48500**	**43300**	**29000**	**11300**	**13500**	**5789**	**1300**	**971**	**1068**	**3825**	**3295**	**3248**
mean weight	405	369	415	426	473	382	351	337	406	395	440	396	357	376
mean length	30.1	28.8	30.2	30.2	30.9	28.6	27.5	27.5	29.5	29.4	30.9	29.6	28.6	28.9

Table 1c: Length composition (absolute frequencies in'000s) of the redfish by-catch in the 3M shrimp fishery, 1993-2002.

Length	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
5								3	8	9
6				150	1	3	14	5	177	56
7			4	4408	96	97	111	58	473	355
8			6	2469	116	222	531	121	1318	623
9			5	216	65	36	784	55	3739	501
10			3	426	235	40	816	191	5795	819
11			14	1081	519	350	377	588	5563	1498
12	2	18	33	861	467	1638	302	997	4429	2784
13	23	331	32	470	149	1540	276	743	1884	4743
14	207	957	59	499	110	304	93	179	662	3795
15	1792	2177	229	749	109	54	87	84	467	1652
16	7171	7115	399	1733	590	104	83	48	459	742
17	27984	17018	703	1190	168	75	59	16	383	351
18	45217	20665	915	755	56	28	40	10	250	238
19	28682	10818	762	386	56	23	37	9	92	143
20	6435	2274	396	69	71	5	12	10	41	73
21	947	312	118	96	55	10	6	4	25	34
22	343	111	25	5	38	12	7	2	23	18
23	1		6		20	7	5	2	12	12
24			2		9	17	2	2	9	6
25			4		3	14	4		4	3
26			4		1	18		2	1	2
27			4			9	3		1	0.4
28			6			1			2	1
29			6			1				0.3
30			2							0.3
31										0.3
32						1				1
33										
34						1				
no ('000)	118805	61798	3739	15563	2933	4609	3651	3126	25810	18459
weight (tons)	11970	5903	374	550	157	191	96	106	738	767
mean weight	0.101	0.096	0.100	0.035	0.054	0.041	0.026	0.034	0.029	0.042
mean length	18.5	18.1	18.3	11.9	14.0	13.1	11.2	12.5	11.5	13.4

6 q

Table 1d: Length composition (absolute frequencies in'000s) of the 3M redfish total annual catch, 1989-2002.

Length	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
5												3	8	9
6								150	1	3	14	5	177	56
7							4	4408	96	97	111	58	473	355
8							6	2469	116	222	531	121	1318	623
9							5	216	65	36	784	55	3739	501
10	3				1		3	426	235	40	816	191	5795	819
11							14	1081	519	350	377	588	5563	1499
12	3				3	18	33	861	467	1638	302	1006	4429	2784
13	12				32	332	32	470	149	1540	276	761	1884	4744
14	29	4			324	969	59	499	110	304	93	180	662	3798
15	9	81			2187	2221	229	749	109	57	87	93	472	1656
16	34	211			7611	7248	399	1755	590	104	83	49	463	752
17	69	808			28151	17409	703	1212	168	76	59	25	405	376
18	34	2787	175		45318	21508	1044	777	56	29	40	36	311	287
19	12	6470	726	70	28812	11848	1052	460	63	32	38	49	137	240
20	128	6925	1494	352	6580	2775	1669	470	79	20	14	78	88	232
21	440	3253	1385	1856	1274	827	3340	1168	70	41	7	56	93	199
22	1316	1344	1323	3110	1313	710	6655	2469	82	69	9	122	149	182
23	4317	2146	1060	2376	1895	732	6438	1825	132	111	6	123	224	199
24	9628	6157	1904	1469	3372	1408	1903	1472	294	146	12	246	310	323
25	16884	13302	4193	2760	3160	1999	1286	872	354	260	126	348	494	486
26	16970	22298	7061	8656	3345	2005	862	569	336	265	116	734	970	606
27	12796	28705	11632	13299	3277	1782	1031	822	213	238	231	1278	1346	812
28	8096	29130	14411	13405	4024	2439	1283	842	183	192	317	1604	1572	1038
29	6605	22485	16923	9609	3530	2587	1594	951	227	186	319	1397	1292	1040
30	8465	16982	14634	8119	5261	2783	1623	998	267	178	210	957	1078	1007
31	7949	11308	8359	5797	4611	2526	1356	1058	240	188	218	662	582	788
32	8432	9266	7907	5124	3629	2196	1405	985	268	173	255	465	368	590
33	8022	7303	3946	4535	3748	1456	1312	761	290	123	185	357	229	481
34	7899	7133	4361	4771	3079	931	1084	742	115	82	89	322	160	290
35	7432	6115	3477	4814	3308	994	1113	310	82	59	150	203	84	143
36	5607	4900	2938	3476	2903	623	1121	218	46	51	81	160	42	93
37	4655	3394	2683	2604	2777	354	985	244	26	50	71	151	34	29
38	2786	2458	1874	1733	1536	303	805	114	29	36	9	128	40	24
39	1787	1734	1959	1388	1318	152	525	139	12	32	31	54	18	18
40	1082	856	1148	974	695	100	504	50	4	17	2	35	11	9
41	577	647	717	583	392	78	372	42	13	12	5	24	5	2
42	390	384	225	233	339	26	176	50	6	9	1	16	7	2
43	332	294	317	274	149	15	74	20	1	3	2	22	3	6
44	155	145	22	199	443	26	54	3	7	2		15	2	
45	163	81	16	45	55	16	37	2	1	0	2	3	1	
46	85	36	9	10	45		8	4	1	1		7	1	
47	53	18			36		20	1	1			4		
48	32	13	9	20	65		5						1	
49	4	13												
50	12	4						30						
51	4	13												
52	4													
53	8	18												
54		9												
55		4												
56														
57														
58		4												
59														
60														
61									12					
no ('000)	143320	219243	116888	101663	180070	91397	42223	32765	6135	7070	6080	12788	35030	27092
weight (tons)	58100	81000	48500	43300	40970	17203	13874	6339	1457	1162	1164	3931	4033	4015

Table 2: 3M beaked redfish abundance at length ('000), biomass and spwanning biomass (tons) from Canadian (1979-1985) and EU (1988-2002) bottom trawl surveys

length	Canadian series						
	1979	1980	1981	1982	1983	1984	1985
5					109		
6	111	7	32	718	849		
7	1324	31	1203	42223	2638	34	12
8	1103	160	659	63441	1839	4015	6
9	143	129	55	9179	9423	2001	24
10	274	177	35	63966	37163	1565	174
11	1059	67	95	158442	41909	2470	567
12	529	81	152	115546	16896	2325	490
13	173	287	137	25360	23079	4035	907
14	390	232	114	1066	45144	7028	1901
15	685	187	75	353	69821	8906	2909
16	1279	191	183	321	23401	8131	5828
17	1915	377	178	360	6088	13438	10431
18	1630	1241	362	325	1336	15159	16987
19	1784	1936	200	510	1174	13987	25321
20	2488	3100	321	584	1059	6307	27476
21	4119	5177	811	709	1393	3893	20043
22	8190	15631	1735	1009	1651	3067	8182
23	13607	40695	3177	1285	2446	3071	1874
24	14554	87273	8900	2097	2721	3582	820
25	8174	100675	22222	4180	3391	4072	979
26	3279	78947	45081	6519	4229	6066	1558
27	882	30072	53109	13886	9660	8742	2766
28	2002	7463	31002	22404	19361	15467	7502
29	4793	7035	14374	19527	26191	28989	16887
30	9915	11480	9282	12581	24800	30685	21750
31	13635	19081	10988	9111	23497	35720	25132
32	19133	26240	15079	9563	21255	29280	19893
33	19992	33798	18861	10828	23609	22260	19161
34	22884	42205	22514	12709	25976	21772	21555
35	21054	42084	21497	14715	24070	18554	20830
36	19388	36351	21739	14251	22765	17724	20012
37	16247	32356	15632	12726	20789	15176	17851
38	11644	23151	14157	9185	16295	10365	12887
39	7992	16055	8858	6858	13188	7404	8091
40	4737	9070	5305	3303	6825	4667	5485
41	2741	4919	3545	2208	3202	2666	2768
42	1240	2574	2068	1979	2184	1772	1683
43	967	947	1301	725	962	863	739
44	384	585	660	458	606	367	380
45	169	177	331	214	315	181	179
46	32	313	101	89	227	90	138
47	41	73	93	0	134	43	28
48	5		26	18	39	24	18
49			22	11	34	6	
50	12	36		6			6
51					6		
52	6						
53							
54					11		
total	246706	682665	356270	675549	583761	385974	352233

	1979	1980	1981	1982	1983	1984	1985
spawning biomass	**57782**	**111684**	**67885**	**45806**	**79349**	**66131**	**63985**
biomass	**123144**	**286971**	**164797**	**112229**	**179117**	**158663**	**146467**
ssb proportion	**46.9%**	**38.9%**	**41.2%**	**40.8%**	**44.3%**	**41.7%**	**43.7%**
mean ssb proportion	**42.1%**						

Table 2 (cont.): 3M beaked redfish abundance at length ('000), biomass and spwanning biomass (tons) from Canadian (1979-1985) and EU (1988-2002) bottom tra

length	EU series													
	1988		1989		1990		1991		1992		1993		1994	
	stock	mat fem	stock	mat fem	stock	mat fem	stock	mat fem	stock	mat fem	stock	mat fem	stock	mat fem
4														
5														
6			10		22		261							
7	300		30		376		14096		950		134			
8	2500		400		4068		95712		31275		535			
9	2800		490		4232		59863		27274		401			
10	2700		800		410		8005		27178		2348		86	
11	8700		2620		261		19838		206880		14178		613	
12	18700		6980		298		27836		306721		23675		1385	
13	14400		8210		1090		10973		92559		19060		3390	
14	2300		19280		2406		2295		21097		65615		20783	
15	500		39630		4031		1945		44512		170339		59296	
16	700		35080		6921		5861		41511		90359		84806	
17	1100		11750		17117		16420		9601		20841		154161	
18	900		2090		20705		30448		5884		6714		169625	
19	3400		1330		12602		50563		9263		3714		92551	
20	6700		2030		2830		60548		15981		2433		25753	
21	15900	133	3120	40	768	10	31124	296	31905	234	2476	22	13029	100
22	34700	488	7270	116	1566	27	8610	120	50785	629	4089	61	7280	122
23	74000	1784	14590	396	3612	117	3230	107	39506	795	6189	175	6862	199
24	117900	5057	27620	1236	9246	411	3520	165	19340	619	7391	327	9043	395
25	131800	9552	44480	3057	20248	1379	7187	405	8638	459	5651	467	10666	691
26	101400	10943	55920	5507	32819	3052	9800	804	11190	677	5587	506	9831	1002
27	45500	6449	48630	6555	34269	4365	10320	1284	15927	1199	4613	406	7154	797
28	19700	3681	32350	6467	25550	5383	9450	1741	18072	2294	4935	523	8858	1367
29	10100	2343	18750	4694	15110	4279	6890	1746	13298	2892	3670	719	7762	1364
30	14200	4076	12110	2983	9550	2835	5980	1836	12040	4213	3615	1009	5589	1423
31	12300	4037	9720	2297	7340	1762	4550	1339	8662	3001	3108	852	4907	1465
32	15100	5582	11380	2666	7120	1992	4110	1377	5818	1810	2588	776	4652	1865
33	15200	6031	8890	3808	6340	2683	4650	2177	5570	1986	2912	884	3312	1033
34	13800	6441	8780	4353	7350	4038	4840	2563	5587	2407	2516	868	2253	624
35	10900	5298	9170	4733	5210	3214	3950	2106	4732	2337	2419	759	2134	789
36	9900	5162	7890	4040	5000	2836	3680	2321	3723	1983	2476	1091	1580	754
37	7600	4238	5930	3104	4010	2434	3020	1785	2976	1847	2431	1271	920	563
38	6900	4478	3960	2592	3040	1954	2580	1826	2481	1680	1599	1092	918	648
39	3700	2720	3600	2807	1820	1265	1660	1275	1815	1417	1356	1035	470	297
40	2500	2024	2530	2185	1230	894	1030	814	1190	1053	808	678	340	268
41	1800	1471	1030	856	630	468	450	388	490	339	363	325	200	159
42	800	677	650	539	310	219	350	309	355	344	362	361	80	80
43	300	263	250	230	190	160	170	160	140	140	101	101	30	20
44	100	88	70	60	40	20	50	40	140	110	170	125	20	20
45	100	88	70	30	50	50	50	30	40	30	34	34	30	20
46			50	50	10	10	50	50	20	20	24	24		
47			20	20	20	10	10	10			23	16		
48			10	10							38	38		
total	731900	93104	469570	65429	279817	45869	535977	27073	1105124	34515	491891	14544	720368	16066

	1988	1989	1990	1991	1992	1993	1994
spawning biomass	**43458**	**32292**	**22890**	**15034**	**18056**	**9046**	**7900**
biomass	**195488**	**123424**	**82238**	**68798**	**104492**	**53804**	**89152**
ssb proportion	**22.2%**	**26.2%**	**27.8%**	**21.9%**	**17.3%**	**16.8%**	**8.9%**
mean catch per tow	178	142	96	143	219	53	101
standard error	57	38	22	25	41	33	54

Table 2 (cont.): 3M beaked redfish abundance at length ('000), biomass and spwanning biomass (tons) from Canadian (1979-1985) and EU (1988-2002) bottom traw surveys

length	EU series															
	1995		1996		1997		1998		1999		2000		2001		2002	
	stock	mat fem	stock	mat fem	stock	mat fem	stock	mat fem	stock	mat fem	stock	mat fem	stock	mat fem	stock	mat fem
4							10									
5							188									
6	28		44		9		47						100		71	
7	12		600				103		79		29		398		924	
8	176		4406		297		719		1126		392		8267		1919	
9	517		3172		784		1589		7822		1972		91234		7959	
10	731		583		548		553		7377		1930		195814		12526	
11	1553		1320		1988		1216		1557		2181		30392		16150	
12	4914		4452		7666		7951		1763		9871		11840		46147	
13	2946		4287		10480		15985		3343		24448		21512		126205	
14	2636		5137		5014		8054		2512		18261		14990		188560	
15	5562		9770		7795		8852		10116		6123		18149		76565	
16	14624		8962		13934		17535		21811		2431		41307		43706	
17	41775		15988		18639		13259		15808		4776		34614		39809	
18	76859		38991		20173		9575		21401		11863		15177		53010	
19	107204		83847		25914		10865		20686		18079		9319		55270	
20	79964		125875		52838		11213		15397		20578		14227		43080	
21	32884	270	118446	904	83129	627	15332	114	11960	187	18149	253	20582	284	23900	326
22	8965	130	77619	988	85180	1213	28529	329	14940	327	17309	419	22548	532	21990	485
23	3872	94	37487	778	57609	1468	50429	1052	26193	907	15587	531	16033	610	18460	668
24	3388	133	18134	713	23549	1113	53764	1912	57574	3009	25380	1003	14914	996	20200	1143
25	4017	266	8735	775	10041	937	33467	1997	74355	6267	48243	2252	14560	1112	16280	1464
26	5219	490	4814	716	6473	1495	15685	1397	59755	7030	71071	6628	18779	1895	15340	1766
27	5085	620	7163	1030	4920	1548	6459	855	22027	4883	76814	15057	18731	2970	14940	1973
28	5776	742	5361	1298	4841	2506	3191	588	7653	2436	55720	16179	14805	3968	13770	3508
29	6134	1067	5864	1582	3524	1586	1557	338	2997	851	23367	8946	8546	3064	10810	4242
30	6137	1532	4251	1148	4238	2341	1062	279	1036	436	5273	2699	6184	2944	6900	3247
31	4976	1490	3697	1309	2731	1176	1279	422	940	399	2126	1225	1871	844	2830	1483
32	4170	1314	3543	1643	2183	995	1066	301	912	321	1199	785	1054	363	1110	598
33	3594	1172	3328	1341	1959	880	900	328	697	324	1480	306	497	230	790	479
34	3079	892	2374	1458	1543	825	796	266	601	218	816	408	596	208	430	194
35	2688	909	1659	787	977	460	467	175	542	207	559	295	312	130	190	80
36	2540	889	1397	891	921	453	510	162	359	225	582	336	260	83	190	61
37	2206	851	1088	719	541	312	340	165	225	182	548	466	110	57	110	42
38	1365	774	785	486	390	196	260	108	137	117	105	91	130	48	100	48
39	978	661	512	348	210	129	170	89	70	60	110	94	60	49	30	10
40	520	397	290	189	146	105	60	30	44	34	70	39	30	10	10	0
41	450	418	260	199	130	110	70	60	20	20	40	30	50	39	10	10
42	330	279	180	130	40	30	30	26	30	10			10	10	10	10
43	160	130	70	50			60	40	10	10	20		40	40	10	
44	40	20	20	20	20	10	30	20			10	10				
45	40	20	20	20			10	10	20	10						
46	40	40					10	10								
47	10	10														
48			10													
total	448164	15610	614540	19520	461374	20514	323247	11074	413895	28467	487511	58050	668041	20487	880311	21837

	1995	1996	1997	1998	1999	2000	2001	2002
spawning bioma	**8682**	**8821**	**8288**	**3665**	**8314**	**19490**	**7016**	**7659**
biomass	**69646**	**92656**	**75575**	**56469**	**77926**	**110438**	**58880**	**85894**
ssb proportion	**12.5%**	**9.5%**	**11.0%**	**6.5%**	**10.7%**	**17.6%**	**11.9%**	**8.9%**
mean catch per	80	111	92	66	91	130	69	104
standard error	17	31	33	21	53	101	22	30

Table 3: Length weight relationships of 3M beaked redfish (Saborido Rey, *pers. comm*. 2003)

	S. mentella		*S. fasciatus*		*Sebastes sp.*	
Year	A	B	A	B	A	B
1989					0.016	2.964
1990					0.023	2.857
1991	0.022	2.861	0.030	2.816	0.031	2.774
1992	0.016	2.968	0.015	3.025	0.025	2.848
1993	0.018	2.938	0.021	2.918	0.023	2.874
1994	0.017	2.951	0.018	2.967	0.023	2.868
1995	0.018	2.937	0.014	3.034	0.024	2.863
1996	0.012	3.046	0.019	2.947	0.018	2.941
1997	0.015	2.983	0.015	3.029	0.025	2.844
1998	0.021	2.891	0.018	2.952	0.026	2.835
1999	0.016	2.958	0.017	2.973	0.020	2.900
2000	0.018	2.937	0.018	2.957	0.023	2.870
2001	0.017	2.953	0.015	3.027	0.025	2.848
2002	0.014	3.016	0.016	2.989	0.020	2.904
1989-00	0.017	2.940	0.018	2.970	0.024	2.849

Table 4a: Stock abundance at age (' 000) of 3M beaked redfish from EU surveys, 1989-02.

year/age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19+	Total
1989	930	18610	101981	11311	5961	28885	80756	85753	44097	22942	14552	9129	8803	8158	7468	4344	3351	3110	9429	469570
1990	8697	2059	39137	27953	1472	9873	41729	55111	31331	16675	10277	6150	6192	5683	4876	2881	2218	2147	5354	279817
1991	169931	66830	5403	105510	93181	15719	20771	15002	9739	5561	5428	4988	4617	3796	1456	1999	1623	926	3498	535977
1992	59499	641604	65635	62451	103409	55934	27966	26574	17983	10987	7403	5599	5337	4086	3722	2450	1484	1016	1989	1105124
1993	1070	87870	75709	253241	8113	19398	10942	7535	2660	3812	3590	3535	2917	3205	2596	1157	1156	1740	1643	491891
1994	0	15021	57871	498187	61409	20396	22182	12328	8563	6091	4988	3685	2806	1626	1837	861	661	797	1061	720368
1995	733	9798	39623	82435	250396	8639	10341	11110	6321	5614	6103	3576	2705	2386	2648	1751	1023	1054	1909	448164
1996	8222	12812	21025	16661	159816	343885	13670	11043	7853	4110	3129	3157	1668	1912	1581	1169	779	702	1348	614540
1997	1638	18015	22083	56738	73641	71026	194508	6070	4841	3819	2143	1935	1080	1325	388	514	614	175	822	461374
1998	3208	25230	39166	24068	26522	45918	29057	119235	4719	620	541	2872	394	403	126	275	502	46	346	323247
1999	16404	7309	27721	49921	33821	32990	44043	39713	150810	6637	353	498	1215	161	358	368	278	611	684	413895
2000	4324	39981	23787	20508	43429	37089	41931	67567	36332	164361	3451	612	234	2123	198	120	127	79	1260	487511
2001	295812	63744	74627	54776	42289	37716	28731	21433	9857	6056	30142	1167	442	269	307	231	92	104	245	668041
2002	23398	231000	262827	172090	49211	41954	29395	23075	19493	5775	3648	16595	810	237	359	133	92	35	185	880311
total	593868	1239881	856594	1435849	952670	769420	596023	501548	354598	263060	95747	63499	39221	35370	27920	18253	13998	12542	29771	

Table 4b: Mature female abundance at age (' 000) of 3M beaked redfish from EU surveys, 1989-02.

year/age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19+	Total
1989				31	119	1324	7287	11793	7735	4676	4109	3351	3968	3925	3829	2259	1920	1742	7359	65429
1990				8	33	539	4275	8504	6139	3750	3141	2511	3119	3020	2806	1679	1330	1276	3737	45869
1991				42	391	796	2273	2929	2606	1943	2318	2477	2510	2222	906	1354	1069	611	2626	27073
1992				12	1196	1491	2174	4489	4709	3630	2767	2308	2602	2188	2103	1610	921	778	1536	34515
1993				0	100	905	958	1191	570	988	1072	1094	1093	1352	1114	1098	766	1164	1078	14544
1994				15	213	1004	2022	1928	1754	1880	1604	1196	919	696	767	448	413	513	694	16066
1995				75	370	382	1079	1736	1367	1575	1909	1110	870	844	972	803	478	579	1460	15610
1996					1232	2489	1797	2283	2130	1459	1315	1450	878	1020	884	698	497	451	936	19520
1997					133	2684	6216	2817	2414	1752	1013	928	524	642	187	271	333	94	508	20514
1998					113	843	1638	5309	987	159	166	950	133	159	42	108	221	15	230	11074
1999					127	1016	3075	5031	15546	1589	144	232	495	61	150	146	136	287	434	28467
2000					258	882	2898	9871	9648	30429	1642	224	147	920	111	84	92	52	792	58050
2001					469	1217	2207	3073	2206	2190	7953	468	159	102	111	86	33	38	176	20487
2002				190	408	1481	1989	2965	3727	2199	1455	6522	432	119	168	46	40	15	79	21837
total				373	5161	17054	39888	63921	61539	58221	30606	24821	17849	17271	14150	10690	8250	7615	21645	

Table 4c: maturity ogive at age for 3M beaked reddish as the average proportion of mature females at age, from the EU survey abundance at age 1989-02.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
Ogive				0.000	0.005	0.022	0.067	0.127	0.174	0.221	0.320	0.391	0.455	0.488	0.507	0.586	0.589	0.607	0.727

Table 5: Catch in numbers at age (' 000) of 3M redfish, 1989-02, including redfish by-catch in the shrimp fishery.

year\age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
1989		19	156	509	1212	9042	26340	27565	16599	11100	10033	7086	7260	6708	5928	3381	2420	2246	5715
1990			6715	11630	3102	6532	32081	52517	36082	20570	12993	7377	6622	6054	4958	2833	2103	1993	5081
1991				1380	4032	7775	20348	25477	18908	9518	7290	5390	4448	3238	1236	1848	1423	874	3704
1992				259	5725	7676	18580	19850	12776	8118	6134	4873	4687	3611	3229	2136	1301	815	1892
1993		302	3753	106478	10881	8511	7170	7255	3327	5242	5105	4852	3680	3947	3271	1552	1197	1836	1709
1994		746	5093	53387	6637	3094	4624	3633	3311	3000	2314	1639	1196	658	783	344	235	290	413
1995	15	78	910	2931	14563	6056	2046	2607	1671	1584	2014	1224	1039	997	1151	896	519	589	1333
1996	7243	3037	2343	1673	3870	5116	1557	1555	1588	1090	849	811	434	447	313	223	149	147	320
1997	513	1109	447	632	136	636	847	294	308	347	236	209	106	129	29	30	32	11	82
1998	398	3291	725	99	61	116	312	771	464	75	83	389	49	54	13	36	72	5	57
1999	2256	963	220	146	42	16	75	277	638	396	88	122	283	42	84	85	74	113	159
2000	434	2389	256	103	161	233	415	1009	1379	4105	650	181	75	649	64	39	35	42	572
2001	11510	11876	1602	752	333	410	911	1414	941	927	3498	414	127	67	71	65	21	32	67
2002	2365	9890	5172	1238	320	509	632	1019	1224	655	809	2266	438	141	203	75	65	12	69
total	24735	33700	27393	181215	51075	55723	115938	145243	99219	66727	52096	36833	30444	26743	21335	13544	9646	9004	21172

Table 6: Weights at age in the catch (Kg) of 3M redfish, 1989-02.

year\age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
1989		0.031	0.076	0.139	0.169	0.207	0.246	0.292	0.345	0.393	0.471	0.530	0.575	0.597	0.641	0.657	0.710	0.720	0.931
1990			0.110	0.123	0.158	0.225	0.281	0.323	0.357	0.388	0.458	0.524	0.581	0.599	0.647	0.664	0.709	0.704	0.933
1991				0.129	0.160	0.255	0.309	0.357	0.391	0.456	0.499	0.551	0.602	0.646	0.693	0.766	0.747	0.779	0.867
1992				0.137	0.173	0.240	0.303	0.352	0.397	0.460	0.537	0.578	0.642	0.679	0.697	0.794	0.748	0.874	0.956
1993		0.055	0.080	0.098	0.138	0.225	0.294	0.373	0.408	0.440	0.511	0.552	0.617	0.678	0.702	0.844	0.818	0.831	1.135
1994		0.048	0.085	0.095	0.130	0.239	0.285	0.359	0.404	0.466	0.499	0.537	0.566	0.667	0.658	0.690	0.795	0.819	0.888
1995	0.011	0.034	0.073	0.147	0.164	0.213	0.296	0.362	0.405	0.456	0.511	0.541	0.621	0.679	0.705	0.781	0.787	0.825	1.000
1996	0.008	0.028	0.062	0.075	0.157	0.180	0.279	0.338	0.399	0.454	0.487	0.544	0.590	0.605	0.660	0.703	0.762	0.801	1.040
1997	0.015	0.031	0.064	0.080	0.137	0.242	0.260	0.362	0.408	0.471	0.509	0.555	0.580	0.585	0.630	0.716	0.748	0.697	1.248
1998	0.011	0.036	0.049	0.093	0.145	0.190	0.286	0.264	0.387	0.437	0.474	0.524	0.588	0.657	0.672	0.767	0.779	0.688	0.958
1999	0.014	0.031	0.057	0.083	0.117	0.174	0.293	0.330	0.317	0.398	0.473	0.564	0.519	0.546	0.534	0.549	0.640	0.579	0.708
2000	0.014	0.033	0.056	0.086	0.140	0.188	0.255	0.305	0.370	0.352	0.460	0.536	0.664	0.571	0.512	0.666	0.722	0.763	0.796
2001	0.017	0.031	0.060	0.093	0.142	0.201	0.254	0.304	0.340	0.388	0.381	0.505	0.574	0.633	0.633	0.580	0.748	0.806	0.926
2002	0.013	0.036	0.054	0.099	0.147	0.206	0.241	0.302	0.332	0.397	0.467	0.425	0.554	0.577	0.600	0.684	0.622	0.855	0.867
mean	0.013	0.036	0.069	0.106	0.149	0.213	0.277	0.330	0.376	0.425	0.481	0.533	0.591	0.623	0.642	0.704	0.738	0.767	0.947

Table 7-A: Weights at age of the 3M beaked redfish stock (Kg) from EU surveys, 1989-02.

year\age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
1989	0.011	0.030	0.057	0.100	0.161	0.204	0.248	0.287	0.322	0.357	0.445	0.523	0.577	0.602	0.646	0.661	0.719	0.723	0.897
1990	0.012	0.033	0.086	0.101	0.174	0.226	0.272	0.309	0.341	0.374	0.456	0.531	0.587	0.608	0.654	0.670	0.727	0.728	0.894
1991	0.013	0.032	0.064	0.112	0.139	0.222	0.284	0.342	0.391	0.468	0.518	0.573	0.620	0.648	0.694	0.754	0.742	0.770	0.862
1992	0.013	0.031	0.066	0.081	0.169	0.207	0.292	0.354	0.398	0.456	0.531	0.575	0.640	0.681	0.703	0.793	0.754	0.874	0.922
1993	0.012	0.040	0.055	0.068	0.162	0.219	0.292	0.368	0.398	0.436	0.514	0.554	0.623	0.682	0.706	0.830	0.823	0.835	1.061
1994		0.049	0.076	0.092	0.133	0.229	0.280	0.352	0.398	0.468	0.498	0.537	0.558	0.674	0.664	0.708	0.801	0.827	0.876
1995	0.013	0.033	0.079	0.111	0.122	0.225	0.293	0.359	0.404	0.452	0.507	0.537	0.615	0.673	0.699	0.768	0.774	0.812	0.993
1996	0.011	0.034	0.061	0.078	0.141	0.143	0.273	0.332	0.390	0.450	0.488	0.543	0.593	0.614	0.666	0.710	0.766	0.799	0.956
1997	0.016	0.037	0.064	0.098	0.135	0.200	0.184	0.357	0.405	0.462	0.499	0.562	0.598	0.608	0.662	0.721	0.752	0.708	0.855
1998	0.014	0.039	0.067	0.097	0.145	0.187	0.236	0.227	0.367	0.415	0.475	0.531	0.598	0.657	0.674	0.762	0.765	0.688	0.997
1999	0.016	0.035	0.066	0.090	0.125	0.180	0.226	0.264	0.249	0.328	0.470	0.565	0.514	0.548	0.538	0.551	0.618	0.595	0.730
2000	0.016	0.038	0.057	0.098	0.135	0.177	0.238	0.288	0.333	0.302	0.424	0.533	0.673	0.571	0.506	0.680	0.722	0.722	0.725
2001	0.018	0.032	0.066	0.092	0.148	0.185	0.242	0.297	0.328	0.379	0.342	0.502	0.578	0.637	0.641	0.599	0.733	0.806	0.927
2002	0.016	0.039	0.055	0.106	0.138	0.189	0.229	0.283	0.321	0.384	0.408	0.392	0.547	0.579	0.612	0.690	0.620	0.842	0.856
mean	0.013	0.036	0.066	0.095	0.145	0.199	0.256	0.316	0.360	0.409	0.470	0.533	0.594	0.627	0.648	0.707	0.737	0.766	0.897

Table 7-B: Weights at age of the 3M mature female beaked redfish stock (Kg) from EU surveys, 1989-02.

year\age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
1989				0.154	0.172	0.219	0.269	0.311	0.342	0.386	0.473	0.551	0.590	0.612	0.651	0.665	0.739	0.741	0.906
1990				0.164	0.187	0.239	0.294	0.333	0.361	0.403	0.484	0.558	0.598	0.619	0.659	0.674	0.741	0.743	0.900
1991				0.154	0.167	0.257	0.309	0.358	0.412	0.476	0.531	0.588	0.632	0.659	0.705	0.766	0.754	0.782	0.880
1992				0.153	0.182	0.224	0.310	0.372	0.414	0.463	0.541	0.595	0.659	0.705	0.727	0.814	0.783	0.887	0.939
1993					0.189	0.232	0.293	0.378	0.413	0.440	0.519	0.558	0.645	0.699	0.719	0.889	0.835	0.844	1.116
1994				0.155	0.172	0.250	0.290	0.360	0.404	0.473	0.506	0.544	0.576	0.700	0.689	0.737	0.808	0.847	0.920
1995				0.161	0.165	0.234	0.304	0.367	0.411	0.455	0.508	0.537	0.621	0.686	0.709	0.786	0.797	0.831	1.008
1996					0.176	0.190	0.285	0.342	0.396	0.457	0.491	0.546	0.596	0.620	0.675	0.715	0.767	0.803	0.961
1997					0.196	0.234	0.254	0.359	0.408	0.461	0.497	0.564	0.601	0.611	0.664	0.722	0.754	0.714	0.881
1998					0.165	0.201	0.270	0.248	0.379	0.428	0.477	0.535	0.600	0.674	0.673	0.766	0.775	0.688	1.030
1999					0.155	0.198	0.244	0.284	0.270	0.351	0.470	0.585	0.525	0.549	0.543	0.554	0.652	0.633	0.758
2000					0.164	0.195	0.275	0.307	0.348	0.332	0.432	0.525	0.686	0.581	0.503	0.699	0.727	0.732	0.747
2001					0.171	0.198	0.250	0.306	0.342	0.385	0.373	0.501	0.582	0.638	0.639	0.604	0.737	0.806	0.954
2002				0.155	0.178	0.212	0.240	0.304	0.336	0.392	0.445	0.402	0.542	0.570	0.599	0.686	0.619	0.837	0.867
mean				0.078	0.174	0.220	0.278	0.331	0.374	0.422	0.482	0.542	0.604	0.637	0.654	0.720	0.749	0.778	0.919

Table 8a: beaked redfish exploitaion pattern given by the generalized logit of the 1989-02 observed partial recruitment.Shaded area in the table corresponds to the PR used inthe Y/R analysis.

Age	F at age index	Observed PR	Logit PR	Squared difference
1	1.306	0.281	0.015	0.069
2	0.782	0.168	0.022	0.015
3	0.513	0.111	0.032	0.005
4	0.691	0.149	0.048	0.013
5	0.339	0.073	0.071	0.000
6	0.515	0.111	0.105	0.000
7	0.981	0.211	0.156	0.003
8	1.219	0.263	0.232	0.001
9	1.507	0.325	0.343	0.000
10	1.905	0.411	0.509	0.010
11	3.768	0.812	0.753	0.003
12	4.482	0.966	0.980	0.000
13	4.640	1.000	1.000	0.000
14	4.544	0.979	1.000	0.000
15	4.023	0.867	1.000	0.016
16	4.411	0.951	1.000	0.001
17	4.164	0.897	1.000	0.008
18	4.297	0.926	1.000	0.002
		Minimum sum of squares		0.054
Curve parameters		a	b	m
		-53.358	4.556	0.087

Table 8b: Female maturity ogive at age for 3M beaked redfish given by a general logit of the 1989-2001 observed maturity at age.

Age	Obs. Mat	Exp. Mat.	Squared difference
1	0	0	0
2	0	0	0
3	0	0	0
4	0.00	0.02	0.000
5	0.01	0.04	0.001
6	0.02	0.06	0.002
7	0.07	0.09	0.001
8	0.13	0.13	0.000
9	0.17	0.18	0.000
10	0.22	0.23	0.000
11	0.32	0.29	0.001
12	0.39	0.35	0.002
13	0.46	0.41	0.002
14	0.49	0.46	0.001
15	0.51	0.52	0.000
16	0.59	0.57	0.000
17	0.59	0.62	0.001
18	0.61	0.67	0.004
Minimum sum of squares			0.015
Curve parameters	a	b	m
	5.322	0.162	1509.175

Table 8c: Yield per recruit parameters for 3M beaked redfish

Age	mean weights 1989-02			% mat females	PR1989-02	Ref. M
	stock	catch	stock mat f			
1	0.016	0.013			0.281	0.20
2	0.039	0.036			0.168	0.20
3	0.055	0.054			0.111	0.10
4	0.106	0.099	0.155	0.021	0.149	0.10
5	0.138	0.147	0.178	0.038	0.071	0.10
6	0.189	0.206	0.212	0.061	0.105	0.10
7	0.229	0.241	0.240	0.093	0.156	0.10
8	0.283	0.302	0.304	0.133	0.232	0.10
9	0.321	0.332	0.336	0.179	0.343	0.10
10	0.384	0.397	0.392	0.232	0.509	0.10
11	0.408	0.467	0.445	0.288	0.753	0.10
12	0.392	0.425	0.402	0.347	0.980	0.10
13	0.547	0.554	0.542	0.407	1.000	0.10
14	0.579	0.577	0.570	0.465	1.000	0.10
15	0.612	0.600	0.599	0.521	1.000	0.10
16	0.690	0.684	0.686	0.575	1.000	0.10
17	0.620	0.622	0.619	0.624	1.000	0.10
18	0.842	0.855	0.837	0.670	1.000	0.10
19+	0.856	0.867	0.867	0.711	1.000	0.10

Table 8d: Fishing mortalities associated with different levels of reduction of spawning and total biomass of 3M beaked redfish (for 1000 reccruits).

	%SSB	%B	%SSB/B	Ref. F	Yield	SSB	B	F	Slope
	100%	100%	49%	0.000	0	1592	3278	0.00	2476
	99%	99%	48%	0.001	2	1570	3245	0.01	1840
	72%	80%	44%	0.025	46	1154	2616	0.03	1237
	66%	75%	43%	0.033	57	1045	2448	0.04	1007
	59%	70%	41%	0.043	67	939	2283	0.05	758
F50%SPR	**50%**	**63%**	**39%**	**0.060**	79	793	2049	0.06	579
	46%	60%	38%	0.068	84	734	1953	0.07	488
	43%	57%	37%	0.076	88	681	1866	0.08	419
F0.1	**34%**	**50%**	**33%**	**0.082**	107	590	1769	0.10	248
	28%	44%	31%	0.129	102	447	1458	0.15	96
	23%	40%	28%	0.162	105	361	1295	0.18	26
	18%	35%	25%	0.205	106	281	1132	0.24	-20
	13%	30%	22%	0.265	105	211	972	0.31	-45
	9%	25%	18%	0.354	101	149	810	0.42	-54
	6%	20%	15%	0.489	94	100	652	0.60	-52
	4%	15%	13%	0.704	83	62	493	0.89	-43
	2%	10%	10%	1.074	67	33	333	1.13	-36

Table 9 : Computation of Z's using female S. mentella length data
(Beverton and Holt, 1957 from Die, D.J. and J.F. Caddy 1997)

1) Mean length in the catch

	1996	1997	1998	1999	2000	2001	2002	mean
$\overline{L}$	27.9	30.9	27.4	30.4	29.9	29.0	30.2	29.3

2) Mean length at age of first capture (age 5)

	1996	1997	1998	1999	2000	2001	2002	mean
Lc	21.8	20.5	21.0	19.8	20.9	20.8	21.2	20.8

3) von Bertalanfy growth parameters

L∞	51.1
K	0.072

4) Length at maturity

Lm	30.14

Z mean 96-01 =	0.183
$Z^*(\overline{L} > L_m) <$	0.162
Assuming M =	0.1
$F^*(\overline{L} > L_m) <$	**0.062**

$$Z = \frac{(L_\infty - \overline{L})K}{(\overline{L} - L_c)}$$

$$Z^* < \frac{(L_\infty - L_m)K}{(L_m - L_c)}$$

Table 10: Lowestoft VPA input files for 3M beaked redfish (2003 assessment)

REDFISH NAFO DIVISION 3M INDEX OF INPUT FILES 2003

1
red3mla.txt
red3mcn.txt
red3mcw.txt
red3msw.txt
red3mnm.txt
red3mmo.txt
red3mpf.txt
red3mpm.txt
red3mfo.txt
red3mfn.txt
red3mtun.txt

REDFISH NAFO 3M LANDINGS tons

1	1
1989	2002
4	19
5	
58088	
80261	
48500	
43300	
40653	
16735	
13805	
6050	
1387	
1002	
1089	
3832	
3381	
3349	

REDFISH NAFO 3M CATCH NUMBERS thousands

1	2														
1989	2002														
4	19														
1															
509	1212	9042	26340	27565	16599	11100	10033	7086	7260	6708	5928	3381	2420	2246	5715
11630	3102	6532	32081	52517	36082	20570	12993	7377	6622	6054	4958	2833	2103	1993	5081
1380	4032	7775	20348	25477	18908	9518	7290	5390	4448	3238	1236	1848	1423	874	3704
259	5725	7676	18580	19850	12776	8118	6134	4873	4687	3611	3229	2136	1301	815	1892
106478	10881	8511	7170	7255	3327	5242	5105	4852	3680	3947	3271	1552	1197	1836	1709
53387	6637	3094	4624	3633	3311	3000	2314	1639	1196	658	783	344	235	290	413
2931	14563	6056	2046	2607	1671	1584	2014	1224	1039	997	1151	896	519	589	1333
1673	3870	5116	1557	1555	1588	1090	849	811	434	447	313	223	149	147	320
632	136	636	847	294	308	347	236	209	106	129	29	30	32	11	82
99	61	116	312	771	464	75	83	389	49	54	13	36	72	5	57
146	42	16	75	277	638	396	88	122	283	42	84	85	74	113	159
103	161	233	415	1009	1379	4105	650	181	75	649	64	39	35	42	572
752	333	410	911	1414	941	927	3498	414	127	67	71	65	21	32	67
1238	320	509	632	1019	1224	655	809	2266	438	141	203	75	65	12	69

REDFISH NAFO 3M CATCH WEIGHT AT AGE kg

1	3														
1989	2002														
4	19														
1															
0.139	0.169	0.207	0.246	0.292	0.345	0.393	0.471	0.530	0.575	0.597	0.641	0.657	0.710	0.720	0.931
0.123	0.158	0.225	0.281	0.323	0.357	0.388	0.458	0.524	0.581	0.599	0.647	0.664	0.709	0.704	0.933
0.129	0.160	0.255	0.309	0.357	0.391	0.456	0.499	0.551	0.602	0.646	0.693	0.766	0.747	0.779	0.867
0.137	0.173	0.240	0.303	0.352	0.397	0.460	0.537	0.578	0.642	0.679	0.697	0.794	0.748	0.874	0.956
0.098	0.138	0.225	0.294	0.373	0.408	0.440	0.511	0.552	0.617	0.678	0.702	0.844	0.818	0.831	1.135
0.095	0.130	0.239	0.285	0.359	0.404	0.466	0.499	0.537	0.566	0.667	0.658	0.690	0.795	0.819	0.888
0.147	0.164	0.213	0.296	0.362	0.405	0.456	0.511	0.541	0.621	0.679	0.705	0.781	0.787	0.825	1.000
0.075	0.157	0.180	0.279	0.338	0.399	0.454	0.487	0.544	0.590	0.605	0.660	0.703	0.762	0.801	1.040
0.080	0.137	0.242	0.260	0.362	0.408	0.471	0.509	0.555	0.580	0.585	0.630	0.716	0.748	0.697	1.248
0.093	0.145	0.190	0.286	0.264	0.387	0.437	0.474	0.524	0.588	0.657	0.672	0.767	0.779	0.688	0.958
0.083	0.117	0.174	0.293	0.330	0.317	0.398	0.473	0.564	0.519	0.546	0.534	0.549	0.640	0.579	0.708
0.086	0.140	0.188	0.255	0.305	0.370	0.352	0.460	0.536	0.664	0.571	0.512	0.666	0.722	0.763	0.796
0.093	0.142	0.201	0.254	0.304	0.340	0.388	0.381	0.505	0.574	0.633	0.633	0.580	0.748	0.806	0.926
0.099	0.147	0.206	0.241	0.302	0.332	0.397	0.467	0.425	0.554	0.577	0.600	0.684	0.622	0.855	0.867

REDFISH NAFO 3M STOCK WEIGHT AT AGE kg

1	4														
1989	2002														
4	19														
1															
0.100	0.161	0.204	0.248	0.287	0.322	0.357	0.445	0.523	0.577	0.602	0.646	0.661	0.719	0.723	0.897
0.101	0.174	0.226	0.272	0.309	0.341	0.374	0.456	0.531	0.587	0.608	0.654	0.670	0.727	0.728	0.894
0.112	0.139	0.222	0.284	0.342	0.391	0.468	0.518	0.573	0.620	0.648	0.694	0.754	0.742	0.770	0.862
0.081	0.169	0.207	0.292	0.354	0.398	0.456	0.531	0.575	0.640	0.681	0.703	0.793	0.754	0.874	0.922
0.068	0.162	0.219	0.292	0.368	0.398	0.436	0.514	0.554	0.623	0.682	0.706	0.830	0.823	0.835	1.061
0.092	0.133	0.229	0.280	0.352	0.398	0.468	0.498	0.537	0.558	0.674	0.664	0.708	0.801	0.827	0.876
0.111	0.122	0.225	0.293	0.359	0.404	0.452	0.507	0.537	0.615	0.673	0.699	0.768	0.774	0.812	0.993
0.078	0.141	0.143	0.273	0.332	0.390	0.450	0.488	0.543	0.593	0.614	0.666	0.710	0.766	0.799	0.956
0.098	0.135	0.200	0.184	0.357	0.405	0.462	0.499	0.562	0.598	0.608	0.662	0.721	0.752	0.708	0.855
0.097	0.145	0.187	0.236	0.227	0.367	0.415	0.475	0.531	0.598	0.657	0.674	0.762	0.765	0.688	0.997
0.090	0.125	0.180	0.226	0.264	0.249	0.328	0.470	0.565	0.514	0.548	0.538	0.551	0.618	0.595	0.730
0.098	0.135	0.177	0.238	0.288	0.333	0.302	0.424	0.533	0.673	0.571	0.506	0.680	0.722	0.722	0.725
0.092	0.148	0.185	0.242	0.297	0.328	0.379	0.342	0.502	0.578	0.637	0.641	0.599	0.733	0.806	0.927
0.106	0.138	0.189	0.229	0.283	0.321	0.384	0.408	0.392	0.547	0.579	0.612	0.690	0.620	0.842	0.856

Table 10: Lowestoft VPA input files for 3M beaked redfish (2003 assessment) (cont)

REDFISH NAFO 3M NATURAL MORTALITY

1 5
1989 2002
4 19
2

0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

REDFISH NAFO 3M PROPORTION MATURE AT AGE

1 6
1989 2002
4 19
2

0.0003	0.0054	0.0222	0.0669	0.1274	0.1735	0.2213	0.3197	0.3909	0.4551	0.4883	0.5068	0.5857	0.5894	0.6072	0.7270

REDFISH NAFO 3M PROPORTION OF F BEFORE SPAWNING

1 7
1989 2002
4 19
3
0.08

REDFISH NAFO 3M PROPORTION OF M BEFORE SPAWNING

1 8
1989 2002
4 19
3
0.08

Table 10: Lowestoft VPA input files for 3M beaked redfish (2003 assessment) (cont.)

REDFISH NAFO 3M F ON OLDEST AGE GROUP BY YEAR

1 9
1989 2002
4 19
5
0.127
0.139
0.093
0.105
0.300
0.065
0.177
0.044
0.003
0.002
0.045
0.031
0.032
0.032

REDFISH NAFO 3M F AT AGE IN LAST YEAR

1 10
1989 2002
4 19
2

0.014	0.014	0.010	0.032	0.047	0.031	0.035	0.028	0.102	0.099	0.082	0.033	0.089	0.027	0.032	0.032

REDFISH NAFO 3M SURVEY TUNNING DATA

101

EU BOTTOM TRAWL SURVEY

1989 2002
1 1 0.5 0.6
4 19

10555	11311	5961	28885	80756	85753	44097	22942	14552	9129	8803	8158	7468	4344	3351	3110	9429
10555	27953	1472	9873	41729	55111	31331	16675	10277	6150	6192	5683	4876	2881	2218	2147	5354
10555	105510	93181	15719	20771	15002	9739	5561	5428	4988	4617	3796	1456	1999	1623	926	3498
10555	62451	103409	55934	27966	26574	17983	10987	7403	5599	5337	4086	3722	2450	1484	1016	1989
10555	253241	8113	19398	10942	7535	2660	3812	3590	3535	2917	3205	2596	1157	1156	1740	1643
10555	498187	61409	20396	22182	12328	8563	6091	4988	3685	2806	1626	1837	861	661	797	1061
10555	82435	250396	8639	10341	11110	6321	5614	6103	3576	2705	2386	2648	1751	1023	1054	1909
10555	16661	159816	343885	13670	11043	7853	4110	3129	3157	1668	1912	1581	1169	779	702	1348
10555	56738	73641	71026	194508	6070	4841	3819	2143	1935	1080	1325	388	514	614	175	822
10555	24068	26522	45918	29057	119235	4719	620	541	2872	394	403	126	275	502	46	346
10555	49921	33821	32990	44043	39713	150810	6637	353	498	1215	161	358	368	278	611	684
10555	20508	43429	37089	41931	67567	36332	164361	3451	612	234	2123	198	120	127	79	1260
10555	54776	42289	37716	28731	21433	9857	6056	30142	1167	442	269	307	231	92	104	245
10555	172090	49211	41954	29395	23075	19493	5775	3648	16595	810	237	359	133	92	35	185

Table 11: Extended Survivor Analysis diagnostics for 2003 (Lowestoft VPA Version 3.1)

REDFISH NAFO DIVISION 3M INDEX OF INPUT FILES 2002
CPUE data from file red3mtun.txt

Catch data for 14 years. 1989 to 2002. Ages 4 to 19.

Fleet	First year	Last year	First age	Last age	Alpha	Beta
EU BOTTOM TRAWL SURV	1989	2002	4	18	0.5	0.6

Time series weights :
Tapered time weighting not applied

Catchability analysis :
Catchability independent of stock size for all ages
Catchability independent of age for ages >= 17

Terminal population estimation :
Final estimates not shrunk towards mean F
Minimum standard error for population
estimates derived from each fleet = .500
Prior weighting not applied
Tuning converged after 964 iterations
Regression weights

1	1	1	1	1	1	1	1	1	1

AGE	4	5	6	7	8	9	10	11	12	13
Taper weighted geometric mean of the VPA populations:	60200	44500	38600	34100	26800	18900	13500	9860	7040	4530
Standard error of the weighted Log(VPA populations) :	0.6891	0.5671	0.7323	0.9322	1.0724	1.1751	1.2516	1.3089	1.3637	1.2121

AGE	14	15	16	17	18
Taper weighted geometric mean of the VPA populations:	3900	3560	3340	3220	3380
Standard error of the weighted Log(VPA populations) :	1.2323	1.1726	1.0825	1.0756	1.0024

Log catchability residuals.
Fleet: EU BOTTOM TRAWL SURVEY

Age	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	
4	-1.8	-0.6	1.04	0.82	1.41	0.54	0.44	-1.01	0.2	-0.46	0.08	-0.61	-0.04	0	
5	-2.5	-3.54	1.05	1.41	-0.58	1.14	0.25	1.45	0.76	-0.29	0.14	0.21	0.38	0.12	
6	-1.27	-1.87	-0.99	0.81	0.16	0.89	-0.38	0.67	0.75	0.35	-0.01	0.3	0.13	0.45	
7	-0.47	-0.63	-0.83	0.07	-0.44	0.78	0.58	0.39	0.12	-0.12	0.31	0.25	0.08	-0.09	
8	-0.16	-0.29	-1.06	0.16	-0.55	0.12	0.61	1.11	-0.27	-0.32	0.24	0.81	-0.35	-0.06	
9	-0.18	-0.29	-1	0.12	-1.21	0.5	0.11	1.11	0.93	-0.12	0.27	0.54	-0.73	-0.04	
10	-0.3	-0.32	-1.09	0.07	-0.41	0.43	0.98	0.33	1.12	-0.64	0.7	0.78	-0.8	-0.83	
11	-0.19	-0.42	-0.64	-0.07	-0.12	0.73	1.35	1.22	0.18	-0.36	-0.79	0.53	-0.52	-0.9	
12	-0.45	-0.71	-0.76	-0.21	-0.31	0.41	0.9	1.27	1.08	0.62	-0.32	-0.1	-0.36	-1.05	
13	-0.12	-0.26	-0.45	-0.13	-0.17	0.06	0.71	0.72	0.72	-0.15	0.15	-0.74	-0.03	-0.31	
14	-0.14	-0.05	-0.32	-0.14	-0.1	-0.36	0.24	0.76	0.77	-0.08	-0.88	1.1	-0.41	-0.38	
15	0.29	0.06	-0.77	0.39	0.21	0.01	0.72	0.36	-0.35	-1.16	0.26	-0.23	-0.25	0.45	
16	0.19	0	-0.2	0.35	-0.05	-0.26	0.52	0.44	-0.35	-0.31	0.32	-0.39	0.38	-0.65	
17	0.05	0.05	-0.05	0	0.2	-0.11	0.34	0.14	0.15	-0.04	0.06	-0.37	-0.3	-0.11	Ssquares
18	0	-0.14	-0.57	-0.27	0.55	0.09	0.6	0.16	-1.23	-2.33	0.29	-1.05	-0.43	-1.14	101.2

Mean log catchability and standard error of ages with catchability
independent of year class strength and constant w.r.t. time

Age	4	5	6	7	8	9	10	11	12	13
Mean Log q	-9.1604	-9.3246	-9.284	-9.1902	-9.1339	-9.3806	-9.6804	-9.9425	-9.8854	-10.0452
S.E(Log q)	0.8542	1.4293	0.8401	0.4648	0.5685	0.6702	0.7301	0.7153	0.7287	0.4446

Age	14	15	16	17	18
Mean Log q	-10.0626	-10.3375	-10.6004	-10.8105	-10.8105
S.E(Log q)	0.5422	0.5094	0.3697	0.1893	0.9087

Regression statistics :
Ages with q independent of year class strength and constant w.r.t. time.

Age	Slope	t-value	Intercept	RSquare	No Pts	Reg s.e	Mean Q
4	0.81	0.681	9.52	0.51	14	0.7	-9.16
5	4.3	-1.107	4.78	0.01	14	6.09	-9.32
6	1.82	-1.483	8.23	0.21	14	1.47	-9.28
7	1.46	-2.851	8.61	0.76	14	0.55	-9.19
8	1.39	-2.163	8.72	0.72	14	0.7	-9.13
9	1.33	-1.658	9.23	0.68	14	0.83	-9.38
10	1.23	-1.192	9.72	0.68	14	0.89	-9.68
11	1.29	-1.549	10.16	0.71	14	0.87	-9.94
12	1.61	-3.45	10.51	0.73	14	0.86	-9.89
13	1.11	-0.954	10.22	0.87	14	0.49	-10.05
14	1.02	-0.184	10.11	0.83	14	0.58	-10.06
15	0.92	0.744	10.16	0.87	14	0.48	-10.34
16	0.93	0.727	10.44	0.91	14	0.35	-10.6
17	0.92	1.975	10.59	0.98	14	0.16	-10.81
18	0.76	1.45	10.47	0.75	14	0.59	-11.2

Table 11: Extended Survivor Analysis diagnostics for 2003 (Lowestoft VPA Version 3.1) (cont)

Terminal year survivor and F summaries :

Age 4 Catchability constant w.r.t. time and dependent on age
Year class = 1998

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU BOTTOM TRAWL SURV	147738	0.884	0	0	1	1	0.008

Age 5 Catchability constant w.r.t. time and dependent on age
Year class = 1997

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU BOTTOM TRAWL SURV	44052	0.759	0.074	0.1	2	1	0.007

Age 6 Catchability constant w.r.t. time and dependent on age
Year class = 1996

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU BOTTOM TRAWL SURV	25835	0.572	0.364	0.64	3	1	0.019

Age 7 Catchability constant w.r.t. time and dependent on age
Year class = 1995

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU BOTTOM TRAWL SURV	28331	0.376	0.063	0.17	4	1	0.021

Age 8 Catchability constant w.r.t. time and dependent on age
Year class = 1994

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU BOTTOM TRAWL SURV	20090	0.317	0.104	0.33	5	1	0.047

Age 9 Catchability constant w.r.t. time and dependent on age
Year class = 1993

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU BOTTOM TRAWL SURV	21286	0.288	0.106	0.37	6	1	0.053

Age 10 Catchability constant w.r.t. time and dependent on age
Year class = 1992

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU BOTTOM TRAWL SURV	18912	0.27	0.277	1.03	7	1	0.032

Age 11 Catchability constant w.r.t. time and dependent on age
Year class = 1991

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU BOTTOM TRAWL SURV	16639	0.254	0.224	0.88	8	1	0.045

Age 12 Catchability constant w.r.t. time and dependent on age
Year class = 1990

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU BOTTOM TRAWL SURV	83032	0.241	0.192	0.8	9	1	0.026

Age 13 Catchability constant w.r.t. time and dependent on age
Year class = 1989

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU BOTTOM TRAWL SURV	2126	0.232	0.138	0.59	10	1	0.179

Age 14 Catchability constant w.r.t. time and dependent on age
Year class = 1988

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU BOTTOM TRAWL SURV	677	0.227	0.184	0.81	11	1	0.181

Age 15 Catchability constant w.r.t. time and dependent on age
Year class = 1987

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU BOTTOM TRAWL SURV	560	0.221	0.192	0.87	12	1	0.296

Age 16 Catchability constant w.r.t. time and dependent on age
Year class = 1986

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU BOTTOM TRAWL SURV	894	0.21	0.163	0.78	13	1	0.077

Age 17 Catchability constant w.r.t. time and dependent on age
Year class = 1985

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU BOTTOM TRAWL SURV	432	0.203	0.156	0.77	14	1	0.134

Age 18 Catchability constant w.r.t. time and age (fixed at the value for age) 17
Year class = 1984

Fleet	Estimated Survivors	Int s.e	Ext s.e	Var Ratio	N	Scaled Weights	Estimated F
EU BOTTOM TRAWL SURV	486	0.206	0.166	0.81	14	1	0.023

Fig. 11b: Retrospective XSA, 2002-2000.

Biomass	2002	2001	2000	02-00 Bias	
1989	309.1	328.1	305.6	1%	under
1990	261.9	278.0	259.5	1%	under
1991	198.7	213.4	197.3	1%	under
1992	139.4	149.9	139.0	0%	
1993	94.9	102.4	95.6	-1%	over
1994	81.8	93.1	92.7	-12%	over
1995	77.0	89.9	92.5	-17%	over
1996	66.6	80.2	86.0	-23%	over
1997	83.4	101.4	109.0	-23%	over
1998	97.5	116.9	126.6	-23%	over
1999	74.4	91.4	106.4	-30%	over
2000	94.4	115.2	130.1	-27%	over
2001	91.9	110.9	01-02 Bias	-17%	over
2002	111.4				

SSB	2002	2001	2000	02-00 Bias	
1989	96.8	107.6	94.5	2%	under
1990	79.7	88.8	77.9	2%	under
1991	67.9	76.3	66.6	2%	under
1992	47.4	53.0	46.6	2%	under
1993	29.5	33.2	29.1	1%	under
1994	19.0	22.0	19.0	0%	
1995	18.0	20.7	17.9	1%	under
1996	13.9	16.4	14.3	-3%	over
1997	22.8	27.2	24.1	-5%	over
1998	29.9	34.8	32.2	-7%	over
1999	12.8	15.8	17.1	-25%	over
2000	22.7	28.5	29.5	-23%	over
2001	20.3	25.6	02-01 Bias	-21%	over
2002	25.5				

Fbar	2002	2001	2000	02-00 Bias	
1989	0.263	0.249	0.265	-1%	over
1990	0.428	0.410	0.430	-1%	over
1991	0.338	0.325	0.339	0%	
1992	0.480	0.456	0.477	1%	under
1993	0.485	0.454	0.481	1%	under
1994	0.327	0.303	0.315	4%	under
1995	0.380	0.343	0.357	6%	under
1996	0.273	0.241	0.248	10%	under
1997	0.076	0.067	0.068	12%	under
1998	0.042	0.034	0.034	26%	under
1999	0.055	0.045	0.044	24%	under
2000	0.097	0.073	0.067	46%	under
2001	0.066	0.053	02-01 Bias	23%	under
2002	0.089				

REC	2002	2001	2000	02-00 Bias	
1989	66	66	65	0%	
1990	55	58	59	-7%	over
1991	36	36	36	0%	
1992	26	27	28	-5%	over
1993	141	143	145	-3%	over
1994	308	362	410	-25%	over
1995	52	63	77	-33%	over
1996	45	57	75	-40%	over
1997	44	50	63	-30%	over
1998	36	42	45	-19%	over
1999	44	56	59	-26%	over
2000	36	28	23	58%	under
2001	55	57	02-01 Bias	-3%	over
2002	165				

Table 12: Extended Survivor Analysis results for 2003 (Lowestoft version 3.1)
Terminal Fs derived using XSA (Without F shrinkage)

(Table 8) Fishing mortality (F) at age

YEAR / AGE	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	FBAR 00-02
4	0.0082	0.2494	0.0406	0.0104	1.5817	0.2012	0.0609	0.0401	0.0151	0.0029	0.0035	0.003	0.0145	0.0079	0.0085
5	0.0157	0.057	0.1149	0.2108	0.6656	0.3094	0.0696	0.096	0.0037	0.0016	0.0013	0.0043	0.0108	0.0069	0.0073
6	0.0851	0.0987	0.1772	0.2959	0.4871	0.3527	0.4552	0.0284	0.0185	0.0035	0.0005	0.0083	0.0121	0.0186	0.013
7	0.2167	0.4283	0.4421	0.7178	0.4393	0.4729	0.3697	0.1789	0.0053	0.0102	0.0025	0.0136	0.0366	0.021	0.0237
8	0.3036	0.7621	0.6334	0.9146	0.6034	0.3695	0.4728	0.4711	0.0417	0.0053	0.0101	0.0379	0.0528	0.0471	0.0459
9	0.2729	0.72	0.6064	0.6732	0.3245	0.5409	0.2577	0.5225	0.1412	0.0772	0.0049	0.0573	0.0406	0.0533	0.0504
10	0.2312	0.5615	0.3673	0.5035	0.5719	0.4812	0.477	0.2382	0.1812	0.0417	0.0788	0.0356	0.0448	0.0324	0.0376
11	0.2829	0.4102	0.3496	0.38	0.6068	0.4723	0.6134	0.4496	0.0665	0.0539	0.0568	0.161	0.0347	0.0452	0.0803
12	0.2594	0.3089	0.2646	0.3699	0.5177	0.3512	0.4353	0.473	0.1677	0.1339	0.0943	0.1425	0.1312	0.0256	0.0997
13	0.3268	0.3652	0.276	0.3441	0.4677	0.2042	0.3492	0.2405	0.0914	0.0485	0.1224	0.0696	0.1264	0.179	0.125
14	0.3137	0.4403	0.2721	0.3357	0.4816	0.1254	0.2341	0.2215	0.0935	0.0554	0.0482	0.4003	0.0738	0.1807	0.2183
15	0.3536	0.3581	0.1333	0.4225	0.5097	0.1458	0.2987	0.096	0.0179	0.011	0.1031	0.0868	0.0614	0.2963	0.1482
16	0.2422	0.2536	0.1953	0.318	0.3275	0.0804	0.2212	0.0775	0.0107	0.0252	0.0832	0.0573	0.1074	0.0768	0.0805
17	0.1587	0.2088	0.1747	0.1836	0.2638	0.067	0.1504	0.0466	0.0129	0.029	0.0596	0.0403	0.0357	0.1338	0.0699
18	0.1518	0.1703	0.1128	0.1287	0.3774	0.0843	0.2133	0.0521	0.0039	0.0022	0.0524	0.0393	0.0424	0.0232	0.035
+gp	0.1518	0.1703	0.1128	0.1287	0.3774	0.0843	0.2133	0.0521	0.0039	0.0022	0.0524	0.0393	0.0424	0.0232	
FBAR 6-16	0.2626	0.4279	0.3379	0.4796	0.4852	0.3269	0.3804	0.2725	0.076	0.0423	0.055	0.0973	0.0656	0.0887	

(Table 9) Relative F at age

YEAR / AGE	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	MEAN 00-02
4	0.0312	0.5829	0.1202	0.0217	3.2599	0.6155	0.16	0.1473	0.1981	0.0675	0.0635	0.0309	0.2208	0.0895	0.1137
5	0.0597	0.1332	0.34	0.4396	1.3719	0.9463	0.1829	0.3525	0.0485	0.0382	0.0244	0.0439	0.1651	0.0776	0.0955
6	0.3242	0.2308	0.5245	0.6171	1.0039	1.0786	1.1966	0.1041	0.2432	0.0823	0.0085	0.085	0.1848	0.2093	0.1597
7	0.8255	1.0009	1.3081	1.4967	0.9054	1.4464	0.9717	0.6566	0.0695	0.24	0.0454	0.1394	0.5572	0.2367	0.3111
8	1.1565	1.7809	1.8744	1.9072	1.2436	1.1301	1.2429	1.729	0.5493	0.1261	0.1833	0.3896	0.8046	0.5311	0.5751
9	1.0392	1.6826	1.7944	1.4038	0.6687	1.6544	0.6775	1.9176	1.8588	1.8244	0.0893	0.5892	0.6192	0.6003	0.6029
10	0.8805	1.3122	1.0869	1.05	1.1787	1.4718	1.254	0.8743	2.3845	0.9844	1.4331	0.366	0.683	0.3653	0.4715
11	1.0776	0.9586	1.0346	0.7923	1.2507	1.4447	1.6126	1.6501	0.8755	1.2739	1.0329	1.6545	0.5294	0.5096	0.8978
12	0.9881	0.7219	0.783	0.7713	1.0669	1.0741	1.1443	1.7359	2.2078	3.162	1.7163	1.4644	1.999	0.2889	1.2508
13	1.2445	0.8534	0.8167	0.7175	0.9639	0.6247	0.918	0.8826	1.203	1.145	2.2264	0.7152	1.9263	2.0172	1.5529
14	1.1947	1.0291	0.8051	0.7	0.9926	0.3835	0.6155	0.8132	1.2311	1.3084	0.8769	4.1152	1.1247	2.0366	2.4255
15	1.3466	0.8368	0.3946	0.881	1.0505	0.4458	0.7852	0.3524	0.2361	0.2594	1.8749	0.8924	0.9354	3.3398	1.7225
16	0.9226	0.5927	0.5778	0.6632	0.675	0.246	0.5815	0.2843	0.1412	0.594	1.5129	0.5891	1.6364	0.8652	1.0302
17	0.6045	0.4879	0.5168	0.3829	0.5437	0.2051	0.3953	0.1709	0.1692	0.6857	1.0844	0.4138	0.5446	1.5085	0.8223
18	0.5783	0.3979	0.3337	0.2684	0.7779	0.2578	0.5607	0.1913	0.0513	0.0528	0.9542	0.4038	0.6461	0.262	0.4373
+gp	0.5783	0.3979	0.3337	0.2684	0.7779	0.2578	0.5607	0.1913	0.0513	0.0528	0.9542	0.4038	0.6461	0.262	
REFMEAN	0.2626	0.4279	0.3379	0.4796	0.4852	0.3269	0.3804	0.2725	0.076	0.0423	0.055	0.0973	0.0656	0.0887	

(Table 10) Stock number at age (start of year) Numbers*10**-3

YEAR / AGE	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	GMST 89-02	AMST 89-02
4	65603	55387	36445	26282	140914	307920	52180	44724	44469	36465	44029	36021	54966	164574	0	55775	74203
5	81990	58876	39053	31664	23535	26219	227834	44426	38877	39636	32900	39700	32496	49020	147738	45318	57059
6	116497	73035	50323	31501	23205	10945	17411	192300	36517	35048	35806	29730	35769	29086	44052	39764	54360
7	142104	96809	59872	38138	21202	12901	6960	9993	169134	32437	31602	32383	26679	31975	25835	34979	54461
8	110657	103526	57080	34818	16835	12364	7274	4352	7561	152233	29054	28524	28907	23273	28331	26893	47023
9	73075	73906	43718	27414	12623	8332	7732	4102	2458	6562	137013	26025	24849	24811	20090	18107	35247
10	56533	50331	32550	21572	12652	8257	4389	5406	2201	1931	5496	123367	22237	21590	21286	12480	27057
11	42800	40594	25975	20399	11797	6462	4618	2465	3855	1662	1676	4596	107723	19239	18912	7638	13908
12	32598	29184	24372	16569	12623	5818	3646	2262	1423	3264	1425	1433	3541	94144	16639	6007	11218
13	27380	22756	19389	16926	10357	6806	3706	2135	1276	1089	2583	1173	1125	2810	83032	5290	9631
14	26190	17868	14291	13313	10856	5870	5021	2365	1519	1053	938	2068	990	897	2126	4936	8446
15	20925	17317	10409	9851	8611	6069	4686	3595	1714	1251	902	809	1254	832	677	4390	7178
16	16521	13295	10953	8243	5842	4680	4746	3145	2955	1524	1120	736	671	1067	560	4199	6147
17	17334	11733	9335	8153	5427	3810	3908	3442	2634	2645	1344	933	629	546	894	4278	5891
18	16762	13383	8616	7093	6139	3772	3224	3042	2973	2353	2325	1146	810	549	432	4436	5902
+gp	42578	34055	36465	16441	5694	5365	7280	6617	22153	26808	3269	15598	1696	3156	3275		
TOTAL	889548	712055	478846	328377	328313	435590	364614	334372	341719	345960	331482	344243	344341	467569	413879		

(Table 11) Spawning stock number at age (spawning time) Numbers*10**-3

YEAR / AGE	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
4														
5	812	581	384	309	221	254	2248	437	386	393	326	394	322	486
6	2296	1438	984	610	443	211	333	3807	723	695	710	589	709	576
7	9698	6496	4013	2501	1421	863	469	684	11740	2251	2194	2246	1847	2217
8	13928	12561	6998	4173	2069	1548	903	540	972	19624	3744	3667	3712	2990
9	12058	11766	7024	4381	2074	1346	1277	664	410	1100	23097	4369	4177	4166
10	12112	10502	6898	4522	2638	1734	922	1158	474	420	1192	26848	4836	4700
11	13283	12471	8018	6282	3568	1975	1396	755	1217	525	530	1440	34102	6085
12	12353	11015	9232	6223	4686	2189	1362	843	543	1249	547	548	1356	36349
13	12172	10085	8655	7514	4553	3056	1644	956	578	495	1167	532	508	1264
14	12415	8385	6797	6300	5078	2825	2395	1129	733	510	454	974	478	430
15	10291	8514	5211	4818	4183	3035	2315	1805	866	633	453	407	631	411
16	9484	7625	6311	4703	3331	2722	2729	1829	1728	890	651	429	389	621
17	10018	6754	5388	4702	3110	2218	2260	2007	1540	1545	783	544	367	316
18	10021	7989	5167	4248	3605	2267	1918	1833	1799	1423	1401	691	489	332
+gp	30462	24329	26170	11785	4001	3859	5183	4772	16038	19410	2357	11260	1224	2281

Table 12 (cont): Extended Survivor Analysis results for 2003 (Lowestoft version 3.1)

(Table 12) Stock biomass at age (start of year) Tonnes

YEAR / AGE	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
4	6560	5594	4082	2129	9582	28329	5792	3489	4358	3537	3963	3530	5057	17445
5	13200	10244	5428	5351	3813	3487	27796	6264	5248	5747	4113	5359	4809	6765
6	23765	16506	11172	6521	5082	2506	3917	27499	7303	6554	6445	5262	6617	5497
7	35242	26332	17004	11136	6191	3612	2039	2728	31121	7655	7142	7707	6456	7322
8	31758	31989	19521	12326	6195	4352	2612	1445	2699	34557	7670	8215	8585	6586
9	23530	25202	17094	10911	5024	3316	3124	1600	996	2408	34116	8666	8151	7964
10	20182	18824	15234	9837	5516	3864	1984	2433	1017	802	1803	37257	8428	8290
11	19046	18511	13455	10832	6064	3218	2341	1203	1924	789	788	1949	36841	7850
12	17049	15497	13965	9527	6993	3125	1958	1228	800	1733	805	764	1777	36904
13	15798	13358	12021	10832	6452	3798	2279	1266	763	651	1328	790	650	1537
14	15766	10864	9261	9066	7404	3957	3379	1452	923	692	514	1181	631	519
15	13518	11325	7224	6925	6080	4030	3275	2394	1135	843	485	409	804	509
16	10921	8908	8258	6537	4849	3314	3645	2233	2130	1161	617	501	402	736
17	12463	8530	6926	6147	4466	3052	3025	2637	1981	2024	831	673	461	338
18	12119	9743	6634	6199	5126	3119	2618	2431	2105	1619	1383	828	653	462
+gp	38193	30445	31433	15159	6042	4700	7229	6326	18941	26727	2386	11308	1572	2701
0 TOTALBIO	309111	261872	198712	139435	94879	81778	77013	66627	83444	97499	74389	94399	91895	111428

(Table 13) Spawning stock biomass at age (spawning time) Tonnes

YEAR / AGE	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
4														
5	131	101	53	52	36	34	274	62	52	57	41	53	48	67
6	468	325	219	126	97	48	75	544	145	130	128	104	131	109
7	2405	1767	1140	730	415	242	137	187	2160	531	496	535	447	508
8	3997	3881	2393	1477	761	545	324	179	347	4455	988	1056	1103	846
9	3883	4012	2746	1744	826	536	516	259	166	404	5751	1455	1370	1337
10	4324	3928	3228	2062	1150	812	417	521	219	174	391	8108	1833	1805
11	5911	5687	4153	3336	1834	984	708	368	607	250	249	611	11663	2483
12	6461	5849	5290	3578	2596	1175	732	458	305	663	309	292	680	14249
13	7023	5920	5366	4809	2836	1705	1011	567	346	296	600	358	294	691
14	7474	5098	4405	4290	3463	1904	1612	693	445	335	249	556	305	249
15	6648	5568	3616	3387	2953	2015	1618	1202	573	426	243	206	405	252
16	6269	5109	4759	3730	2765	1927	2096	1299	1246	678	359	292	233	428
17	7203	4910	3998	3545	2559	1777	1749	1538	1158	1182	484	393	269	196
18	7245	5816	3979	3713	3010	1875	1557	1465	1273	979	834	499	394	279
+gp	27325	21750	22559	10865	4245	3381	5147	4562	13712	19352	1721	8164	1134	1952
0 TOTSPBIO	96767	79721	67903	47446	29546	18958	17974	13903	22756	29912	12843	22681	20308	25451

Table 16 Summary (without SOP correction)

	RECRUITS Age 4	TOTALBIO	TOTSPBIO	LANDINGS	YIELD/SSB	FBAR 6-16	ABUNDANCE
1989	65603	309111	96767	58088	0.6003	0.2626	889548
1990	55387	261872	79721	80261	1.0068	0.4279	712055
1991	36445	198712	67903	48500	0.7143	0.3379	478846
1992	26282	139435	47446	43300	0.9126	0.4796	328377
1993	140914	94879	29546	40653	1.3759	0.4852	328313
1994	307920	81778	18958	16735	0.8827	0.3269	435590
1995	52180	77013	17974	13805	0.7681	0.3804	364614
1996	44724	66627	13903	6050	0.4352	0.2725	334372
1997	44469	83444	22756	1387	0.0610	0.0760	341719
1998	36465	97499	29912	1002	0.0335	0.0423	345960
1999	44029	74389	12843	1089	0.0848	0.0550	331482
2000	36021	94399	22681	3832	0.1689	0.0973	344243
2001	54966	91895	20308	3381	0.1665	0.0656	344341
2002	164574	111428	25451	3349	0.1316	0.0887	467569
Arith. Mean	79284	127320	36155	22959	0.5244	0.2427	
Units	(Thousands)	(Tonnes)	(Tonnes)	(Tonnes)			

Tab. 13a: ASPIC input file

```
'BOT'                       ## Mode (FIT, IRF, BOT)
'Div. 3M redfish'
'EFF'                       ## Error type ('EFF' = condition on yield)
 2                          ## Verbosity (0 to 4)
 1000                        ## Number of bootstrap trials, <= 1000
 0 10000                    ## Monte Carlo search enable (0,1,2), N trials
 1.0E-8                     ## Convergence crit. for simplex
 3.0E-8                     ## Convergence crit. for restarts
 1.0d-4                     ## Convergence crit. for estimating effort
 1.5d0                      ## Maximum F when estimating effort
 0.0d0                     ## Statistical weight for B1 > K as residual
 2                          ## Number of data series (fisheries)
1.0d0 1.0d0                    ## Statistical weights for fisheries
2.0d0                       ## B1-ratio (starting guess)
2.0d4                       ## MSY (starting guess)
0.16d0                       ## r (starting guess)
0.657107d0 0.0d0               ## q (starting guess)
1 1 1 0 1                 ## Flags to estimate parameters
0.5d4  5.0d4                ## Min and max allowable MSY
0.05d0  1.0d0              ## Min and max allowable r
9126738                     ## Random number seed
44                          ## Number of years of data.
'EU survey'                 ## Title for first series
'I1'                        ## Type of series ('CE' = effort, catch)
 1959   -0.001
 1960   -0.001
 1961   -0.001
 1962   -0.001
 1963   -0.001
 1964   -0.001
 1965   -0.001
 1966   -0.001
 1967   -0.001
 1968   -0.001
 1969   -0.001
 1970   -0.001
 1971   -0.001
 1972   -0.001
 1973   -0.001
 1974   -0.001
 1975   -0.001
 1976   -0.001
 1977   -0.001
 1978   -0.001
 1979   -0.001
 1980   -0.001
 1981   -0.001
 1982   -0.001
 1983   -0.001
 1984   -0.001
 1985   -0.001
 1986   -0.001
 1987   -0.001
 1988      193567.0
 1989      117015.0
 1990       78703.0
 1991       64126.0
```

```
 1992       85620.0
 1993       46218.0
 1994       86359.0
 1995       68804.0
 1996       94955.0
 1997       76785.0
 1998       54039.0
 1999       77468.0
 2000      110019.0
 2001       49147.0
 2002       63787.0
'Statlant CPUE'
'CC'
 1959   2.688   51977.0
 1960   4.179    8388.0
 1961   5.331   15517.0
 1962   3.691    6958.0
 1963   3.762    7035.0
 1964   2.245   17647.0
 1965   3.278   33427.0
 1966   1.771    7241.0
 1967   1.818     729.0
 1968   3.441    4963.0
 1969   2.924    2801.0
 1970   7.274    3168.0
 1971   5.020    8033.0
 1972   2.940   41946.0
 1973   2.563   22352.0
 1974   3.199   34671.0
 1975   3.138   16075.0
 1976   2.377   16998.0
 1977   2.128   20267.0
 1978   2.522   16762.0
 1979   1.739   20074.0
 1980   2.222   15957.0
 1981   2.530   13891.0
 1982   2.359   14684.0
 1983   2.134   19527.0
 1984   2.121   20228.0
 1985   2.188   20282.0
 1986   3.202   28873.0
 1987   3.582   44411.0
 1988   2.108   23189.0
 1989   1.658   58102.0
 1990   1.574   81046.0
 1991   1.484   48489.0
 1992   1.530   43317.0
 1993   1.732   28993.0
 1994  -0.001   11315.0
 1995  -0.001   13495.0
 1996  -0.001    5789.0
 1997  -0.001    1300.0
 1998  -0.001     971.0
 1999  -0.001    1068.0
 2000  -0.001    3825.0
 2001  -0.001    3295.0
 2002  -0.001    3348.0
```

Table 13b: ASPIC output on bootstrap mode
Div. 3M redfish

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20 May 2003 at 11:00

ASPIC -- A Surplus-Production Model Including Covariates (Ver. 3.65) BOT Mode

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Southwest Fisheries Science Center
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Tiburon, California 94920 USA

CONTROL PARAMETERS USED (FROM INPUT FILE)

Number of years analyzed:	44	Number of bootstrap trials:	1000
Number of data series:	2	Lower bound on MSY:	5.000E+03
Objective function computed:	in EFFORT	Upper bound on MSY:	5.000E+04
Relative conv. criterion (simplex):	1.000E-08	Lower bound on r:	5.000E-02
Relative conv. criterion (restart):	3.000E-08	Upper bound on r:	1.000E+00
Relative conv. criterion (effort):	1.000E-04	Random number seed:	9126738
Maximum F allowed in fitting:	1.500	Monte Carlo search trials:	0

PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS) code 0

Normal convergence.

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)

	1	2
1 EU survey	1.000 15	
2 Statlant CPUE	0.808 6	1.000 35

GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS

Loss component number and title	Weighted SSE	N	Weighted MSE	Current weight	Suggested weight	R-squared in CPUE
Loss(-1) SSE in yield	0.000E+00					
Loss(0) Penalty for B1R > 2	0.000E+00	1	N/A	0.000E+00	N/A	
Loss(1) EU survey	1.901E+00	15	1.462E-01	1.000E+00	8.049E-01	0.245
Loss(2) Statlant CPUE	3.584E+00	35	1.086E-01	1.000E+00	1.084E+00	0.288

TOTAL OBJECTIVE FUNCTION: 5.48481730E+00

Number of restarts required for convergence: 2
Est. B-ratio coverage index (0 worst, 2 best): 1.4155

Est. B-ratio nearness index (0 worst, 1 best): 1.0000

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	Starting guess	Estimated	User guess
B1R	Starting biomass ratio, year 1959	1.766E+00	2.000E+00	1	1
MSY	Maximum sustainable yield	1.722E+04	2.000E+04	1	1
r	Intrinsic rate of increase	1.366E-01	1.600E-01	1	1
....	Catchability coefficients by fishery:				
q(1)	EU survey	6.571E-01	6.571E-01	0	1
q(2)	Statlant CPUE	8.001E-06	4.114E-05	1	0

MANAGEMENT PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	Formula	
MSY	Maximum sustainable yield	1.722E+04	Kr/4	
K	Maximum stock biomass	5.041E+05		
Bmsy	Stock biomass at MSY	2.521E+05	K/2	
Fmsy	Fishing mortality at MSY	6.832E-02	r/2	
F(0.1)	Management benchmark	6.148E-02	0.9*Fmsy	
Y(0.1)	Equilibrium yield at F(0.1)	1.705E+04	0.99*MSY	
B-ratio	Ratio of B(2003) to Bmsy	6.141E-01		
F-ratio	Ratio of F(2002) to Fmsy	3.283E-01		
Y-ratio	Proportion of MSY avail in 2003	8.511E-01	2*Br-Br^2	Ye(2003) = 1.466E+04
....	Fishing effort at MSY in units of each fishery:			
fmsy(2)	Statlant CPUE	8.538E+03	r/2q(2)	f(0.1) = 7.685E+03

ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

Obs	Year or ID	Estimated total F mort	Estimated starting biomass	Estimated average biomass	Observed total yield	Model total yield	Estimated surplus production	Ratio of F mort to Fmsy	Ratio of biomass to Bmsy
1	1959	0.123	4.452E+05	4.231E+05	5.198E+04	5.198E+04	9.252E+03	1.798E+00	1.766E+00
2	1960	0.021	4.025E+05	4.038E+05	8.388E+03	8.388E+03	1.098E+04	3.041E-01	1.597E+00
3	1961	0.039	4.051E+05	4.028E+05	1.552E+04	1.552E+04	1.106E+04	5.639E-01	1.607E+00
4	1962	0.017	4.006E+05	4.027E+05	6.958E+03	6.958E+03	1.107E+04	2.529E-01	1.589E+00
5	1963	0.017	4.047E+05	4.066E+05	7.035E+03	7.035E+03	1.075E+04	2.533E-01	1.606E+00
6	1964	0.044	4.085E+05	4.050E+05	1.765E+04	1.765E+04	1.088E+04	6.378E-01	1.620E+00
7	1965	0.086	4.017E+05	3.907E+05	3.343E+04	3.343E+04	1.200E+04	1.252E+00	1.594E+00
8	1966	0.019	3.803E+05	3.830E+05	7.241E+03	7.241E+03	1.258E+04	2.768E-01	1.509E+00
9	1967	0.002	3.856E+05	3.913E+05	7.290E+02	7.290E+02	1.196E+04	2.727E-02	1.530E+00
10	1968	0.012	3.968E+05	4.000E+05	4.963E+03	4.963E+03	1.129E+04	1.816E-01	1.574E+00
11	1969	0.007	4.032E+05	4.072E+05	2.801E+03	2.801E+03	1.070E+04	1.007E-01	1.599E+00
12	1970	0.008	4.111E+05	4.146E+05	3.168E+03	3.168E+03	1.006E+04	1.119E-01	1.631E+00
13	1971	0.019	4.179E+05	4.188E+05	8.033E+03	8.033E+03	9.687E+03	2.808E-01	1.658E+00
14	1972	0.104	4.196E+05	4.036E+05	4.195E+04	4.195E+04	1.097E+04	1.521E+00	1.665E+00
15	1973	0.058	3.886E+05	3.836E+05	2.235E+04	2.235E+04	1.253E+04	8.529E-01	1.542E+00
16	1974	0.094	3.788E+05	3.680E+05	3.467E+04	3.467E+04	1.357E+04	1.379E+00	1.503E+00
17	1975	0.045	3.577E+05	3.568E+05	1.608E+04	1.608E+04	1.425E+04	6.595E-01	1.419E+00
18	1976	0.048	3.559E+05	3.545E+05	1.700E+04	1.700E+04	1.437E+04	7.018E-01	1.412E+00
19	1977	0.058	3.533E+05	3.504E+05	2.027E+04	2.027E+04	1.460E+04	8.467E-01	1.401E+00
20	1978	0.048	3.476E+05	3.466E+05	1.676E+04	1.676E+04	1.480E+04	7.079E-01	1.379E+00
21	1979	0.059	3.456E+05	3.430E+05	2.007E+04	2.007E+04	1.498E+04	8.566E-01	1.371E+00
22	1980	0.047	3.405E+05	3.401E+05	1.596E+04	1.596E+04	1.512E+04	6.868E-01	1.351E+00
23	1981	0.041	3.397E+05	3.403E+05	1.389E+04	1.389E+04	1.511E+04	5.975E-01	1.348E+00
24	1982	0.043	3.409E+05	3.411E+05	1.468E+04	1.468E+04	1.507E+04	6.301E-01	1.352E+00
25	1983	0.058	3.413E+05	3.391E+05	1.953E+04	1.953E+04	1.517E+04	8.430E-01	1.354E+00
26	1984	0.060	3.369E+05	3.345E+05	2.023E+04	2.023E+04	1.538E+04	8.853E-01	1.337E+00
27	1985	0.062	3.321E+05	3.297E+05	2.028E+04	2.028E+04	1.559E+04	9.005E-01	1.317E+00
28	1986	0.090	3.274E+05	3.208E+05	2.887E+04	2.887E+04	1.594E+04	1.318E+00	1.299E+00
29	1987	0.148	3.145E+05	3.001E+05	4.441E+04	4.441E+04	1.658E+04	2.166E+00	1.247E+00
30	1988	0.082	2.866E+05	2.835E+05	2.319E+04	2.319E+04	1.695E+04	1.198E+00	1.137E+00
31	1989	0.224	2.804E+05	2.591E+05	5.810E+04	5.810E+04	1.717E+04	3.282E+00	1.112E+00
32	1990	0.395	2.395E+05	2.052E+05	8.105E+04	8.105E+04	1.653E+04	5.781E+00	9.499E-01
33	1991	0.308	1.749E+05	1.574E+05	4.849E+04	4.849E+04	1.476E+04	4.511E+00	6.940E-01
34	1992	0.346	1.412E+05	1.253E+05	4.332E+04	4.332E+04	1.284E+04	5.062E+00	5.602E-01
35	1993	0.286	1.107E+05	1.015E+05	2.899E+04	2.899E+04	1.107E+04	4.183E+00	4.393E-01
36	1994	0.123	9.281E+04	9.230E+04	1.132E+04	1.132E+04	1.030E+04	1.795E+00	3.682E-01
37	1995	0.150	9.180E+04	9.008E+04	1.350E+04	1.350E+04	1.011E+04	2.193E+00	3.642E-01
38	1996	0.064	8.841E+04	9.058E+04	5.789E+03	5.789E+03	1.015E+04	9.355E-01	3.507E-01
39	1997	0.013	9.277E+04	9.744E+04	1.300E+03	1.300E+03	1.074E+04	1.953E-01	3.680E-01
40	1998	0.009	1.022E+05	1.074E+05	9.710E+02	9.710E+02	1.155E+04	1.323E-01	4.055E-01
41	1999	0.009	1.128E+05	1.184E+05	1.068E+03	1.068E+03	1.237E+04	1.321E-01	4.474E-01
42	2000	0.030	1.241E+05	1.287E+05	3.825E+03	3.825E+03	1.309E+04	4.351E-01	4.923E-01
43	2001	0.024	1.334E+05	1.385E+05	3.295E+03	3.295E+03	1.372E+04	3.481E-01	5.291E-01
44	2002	0.022	1.438E+05	1.493E+05	3.348E+03	3.348E+03	1.435E+04	3.283E-01	5.704E-01
45	2003		1.548E+05						6.141E-01

RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED) EU survey

Data type I1: Year-average biomass index Series weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Resid in index
1	1959	0.000E+00	0.000E+00	0.0	*	2.780E+05	0.00000	0.0
2	1960	0.000E+00	0.000E+00	0.0	*	2.653E+05	0.00000	0.0
3	1961	0.000E+00	0.000E+00	0.0	*	2.647E+05	0.00000	0.0
4	1962	0.000E+00	0.000E+00	0.0	*	2.646E+05	0.00000	0.0
5	1963	0.000E+00	0.000E+00	0.0	*	2.672E+05	0.00000	0.0
6	1964	0.000E+00	0.000E+00	0.0	*	2.661E+05	0.00000	0.0
7	1965	0.000E+00	0.000E+00	0.0	*	2.567E+05	0.00000	0.0
8	1966	0.000E+00	0.000E+00	0.0	*	2.517E+05	0.00000	0.0
9	1967	0.000E+00	0.000E+00	0.0	*	2.571E+05	0.00000	0.0
10	1968	0.000E+00	0.000E+00	0.0	*	2.629E+05	0.00000	0.0
11	1969	0.000E+00	0.000E+00	0.0	*	2.675E+05	0.00000	0.0
12	1970	0.000E+00	0.000E+00	0.0	*	2.724E+05	0.00000	0.0
13	1971	0.000E+00	0.000E+00	0.0	*	2.752E+05	0.00000	0.0
14	1972	0.000E+00	0.000E+00	0.0	*	2.652E+05	0.00000	0.0
15	1973	0.000E+00	0.000E+00	0.0	*	2.521E+05	0.00000	0.0
16	1974	0.000E+00	0.000E+00	0.0	*	2.418E+05	0.00000	0.0
17	1975	0.000E+00	0.000E+00	0.0	*	2.344E+05	0.00000	0.0
18	1976	0.000E+00	0.000E+00	0.0	*	2.330E+05	0.00000	0.0
19	1977	0.000E+00	0.000E+00	0.0	*	2.302E+05	0.00000	0.0
20	1978	0.000E+00	0.000E+00	0.0	*	2.277E+05	0.00000	0.0
21	1979	0.000E+00	0.000E+00	0.0	*	2.254E+05	0.00000	0.0
22	1980	0.000E+00	0.000E+00	0.0	*	2.235E+05	0.00000	0.0
23	1981	0.000E+00	0.000E+00	0.0	*	2.236E+05	0.00000	0.0
24	1982	0.000E+00	0.000E+00	0.0	*	2.241E+05	0.00000	0.0
25	1983	0.000E+00	0.000E+00	0.0	*	2.228E+05	0.00000	0.0
26	1984	0.000E+00	0.000E+00	0.0	*	2.198E+05	0.00000	0.0
27	1985	0.000E+00	0.000E+00	0.0	*	2.166E+05	0.00000	0.0
28	1986	0.000E+00	0.000E+00	0.0	*	2.108E+05	0.00000	0.0
29	1987	0.000E+00	0.000E+00	0.0	*	1.972E+05	0.00000	0.0
30	1988	1.000E+00	1.000E+00	0.0	1.936E+05	1.863E+05	0.03849	7.308E+03
31	1989	1.000E+00	1.000E+00	0.0	1.170E+05	1.703E+05	-0.37516	-5.327E+04
32	1990	1.000E+00	1.000E+00	0.0	7.870E+04	1.348E+05	-0.53844	-5.614E+04
33	1991	1.000E+00	1.000E+00	0.0	6.413E+04	1.034E+05	-0.47773	-3.927E+04
34	1992	1.000E+00	1.000E+00	0.0	8.562E+04	8.232E+04	0.03936	3.304E+03
35	1993	1.000E+00	1.000E+00	0.0	4.622E+04	6.667E+04	-0.36645	-2.046E+04
36	1994	1.000E+00	1.000E+00	0.0	8.636E+04	6.065E+04	0.35340	2.571E+04
37	1995	1.000E+00	1.000E+00	0.0	6.880E+04	5.920E+04	0.15042	9.609E+03
38	1996	1.000E+00	1.000E+00	0.0	9.496E+04	5.952E+04	0.46706	3.543E+04
39	1997	1.000E+00	1.000E+00	0.0	7.678E+04	6.403E+04	0.18173	1.276E+04
40	1998	1.000E+00	1.000E+00	0.0	5.404E+04	7.060E+04	-0.26729	-1.656E+04
41	1999	1.000E+00	1.000E+00	0.0	7.747E+04	7.779E+04	-0.00412	-3.201E+02
42	2000	1.000E+00	1.000E+00	0.0	1.100E+05	8.457E+04	0.26310	2.545E+04
43	2001	1.000E+00	1.000E+00	0.0	4.915E+04	9.104E+04	-0.61645	-4.189E+04
44	2002	1.000E+00	1.000E+00	0.0	6.379E+04	9.808E+04	-0.43024	-3.429E+04

* Asterisk indicates missing value(s).

```
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 1
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    --------------------------------------------------------------------------
1959     0.0000                                             |
1960     0.0000                                             |
1961     0.0000                                             |
1962     0.0000                                             |
1963     0.0000                                             |
1964     0.0000                                             |
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0000                                             |
1972     0.0000                                             |
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984     0.0000                                             |
1985     0.0000                                             |
1986     0.0000                                             |
1987     0.0000                                             |
1988     0.0385                                             |==
1989    -0.3752                              ===============|
1990    -0.5384                       ======================|
1991    -0.4777                          ===================|
1992     0.0394                                             |==
1993    -0.3664                              ===============|
1994     0.3534                                             |==============
1995     0.1504                                             |======
1996     0.4671                                             |===================
1997     0.1817                                             |=======
1998    -0.2673                                  ===========|
1999    -0.0041                                             |
2000     0.2631                                             |===========
2001    -0.6165                    =========================|
2002    -0.4302                            =================|
                   --------------------------------------------------------------------------
```

RESULTS FOR DATA SERIES # 2 (NON-BOOTSTRAPPED) Statlant CPUE

Data type CC: CPUE-catch series Series weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed yield	Model yield	Resid in log effort	Resid in yield
1	1959	1.934E+04	1.535E+04	0.1229	5.198E+04	5.198E+04	0.23058	0.000E+00
2	1960	2.007E+03	2.596E+03	0.0208	8.388E+03	8.388E+03	-0.25733	0.000E+00
3	1961	2.911E+03	4.815E+03	0.0385	1.552E+04	1.552E+04	-0.50327	0.000E+00
4	1962	1.885E+03	2.159E+03	0.0173	6.958E+03	6.958E+03	-0.13586	0.000E+00
5	1963	1.870E+03	2.162E+03	0.0173	7.035E+03	7.035E+03	-0.14526	0.000E+00
6	1964	7.861E+03	5.446E+03	0.0436	1.765E+04	1.765E+04	0.36697	0.000E+00
7	1965	1.020E+04	1.069E+04	0.0856	3.343E+04	3.343E+04	-0.04753	0.000E+00
8	1966	4.089E+03	2.363E+03	0.0189	7.241E+03	7.241E+03	0.54820	0.000E+00
9	1967	4.010E+02	2.329E+02	0.0019	7.290E+02	7.290E+02	0.54350	0.000E+00
10	1968	1.442E+03	1.551E+03	0.0124	4.963E+03	4.963E+03	-0.07240	0.000E+00
11	1969	9.579E+02	8.598E+02	0.0069	2.801E+03	2.801E+03	0.10806	0.000E+00
12	1970	4.355E+02	9.551E+02	0.0076	3.168E+03	3.168E+03	-0.78530	0.000E+00
13	1971	1.600E+03	2.397E+03	0.0192	8.033E+03	8.033E+03	-0.40426	0.000E+00
14	1972	1.427E+04	1.299E+04	0.1039	4.195E+04	4.195E+04	0.09390	0.000E+00
15	1973	8.721E+03	7.283E+03	0.0583	2.235E+04	2.235E+04	0.18025	0.000E+00
16	1974	1.084E+04	1.178E+04	0.0942	3.467E+04	3.467E+04	-0.08302	0.000E+00
17	1975	5.123E+03	5.631E+03	0.0451	1.608E+04	1.608E+04	-0.09468	0.000E+00
18	1976	7.151E+03	5.992E+03	0.0479	1.700E+04	1.700E+04	0.17679	0.000E+00
19	1977	9.524E+03	7.230E+03	0.0578	2.027E+04	2.027E+04	0.27560	0.000E+00
20	1978	6.646E+03	6.045E+03	0.0484	1.676E+04	1.676E+04	0.09488	0.000E+00
21	1979	1.154E+04	7.314E+03	0.0585	2.007E+04	2.007E+04	0.45630	0.000E+00
22	1980	7.181E+03	5.864E+03	0.0469	1.596E+04	1.596E+04	0.20264	0.000E+00
23	1981	5.491E+03	5.102E+03	0.0408	1.389E+04	1.389E+04	0.07343	0.000E+00
24	1982	6.225E+03	5.380E+03	0.0430	1.468E+04	1.468E+04	0.14575	0.000E+00
25	1983	9.150E+03	7.198E+03	0.0576	1.953E+04	1.953E+04	0.24003	0.000E+00
26	1984	9.537E+03	7.559E+03	0.0605	2.023E+04	2.023E+04	0.23246	0.000E+00
27	1985	9.270E+03	7.689E+03	0.0615	2.028E+04	2.028E+04	0.18700	0.000E+00
28	1986	9.017E+03	1.125E+04	0.0900	2.887E+04	2.887E+04	-0.22120	0.000E+00
29	1987	1.240E+04	1.849E+04	0.1480	4.441E+04	4.441E+04	-0.39989	0.000E+00
30	1988	1.100E+04	1.022E+04	0.0818	2.319E+04	2.319E+04	0.07310	0.000E+00
31	1989	3.504E+04	2.802E+04	0.2242	5.810E+04	5.810E+04	0.22356	0.000E+00
32	1990	5.149E+04	4.936E+04	0.3949	8.105E+04	8.105E+04	0.04221	0.000E+00
33	1991	3.267E+04	3.852E+04	0.3082	4.849E+04	4.849E+04	-0.16446	0.000E+00
34	1992	2.831E+04	4.322E+04	0.3458	4.332E+04	4.332E+04	-0.42300	0.000E+00
35	1993	1.674E+04	3.571E+04	0.2857	2.899E+04	2.899E+04	-0.75775	0.000E+00
36	1994	*	1.532E+04	0.1226	1.132E+04	1.132E+04	0.00000	0.000E+00
37	1995	*	1.872E+04	0.1498	1.350E+04	1.350E+04	0.00000	0.000E+00
38	1996	*	7.988E+03	0.0639	5.789E+03	5.789E+03	0.00000	0.000E+00
39	1997	*	1.668E+03	0.0133	1.300E+03	1.300E+03	0.00000	0.000E+00
40	1998	*	1.130E+03	0.0090	9.710E+02	9.710E+02	0.00000	0.000E+00
41	1999	*	1.128E+03	0.0090	1.068E+03	1.068E+03	0.00000	0.000E+00
42	2000	*	3.715E+03	0.0297	3.825E+03	3.825E+03	0.00000	0.000E+00
43	2001	*	2.973E+03	0.0238	3.295E+03	3.295E+03	0.00000	0.000E+00
44	2002	*	2.803E+03	0.0224	3.348E+03	3.348E+03	0.00000	0.000E+00

* Asterisk indicates missing value(s).

```
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 2
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    -------------------------------------------------------------------------------------
1959     0.2306                                             |=========
1960    -0.2573                                   ==========|
1961    -0.5033                         ====================|
1962    -0.1359                                        =====|
1963    -0.1453                                       ======|
1964     0.3670                                             |===============
1965    -0.0475                                           ==|
1966     0.5482                                             |======================
1967     0.5435                                             |======================
1968    -0.0724                                          ===|
1969     0.1081                                             |====
1970    -0.7853              ===============================|
1971    -0.4043                             ================|
1972     0.0939                                             |====
1973     0.1802                                             |=======
1974    -0.0830                                          ===|
1975    -0.0947                                         ====|
1976     0.1768                                             |=======
1977     0.2756                                             |===========
1978     0.0949                                             |====
1979     0.4563                                             |==================
1980     0.2026                                             |========
1981     0.0734                                             |===
1982     0.1458                                             |======
1983     0.2400                                             |==========
1984     0.2325                                             |=========
1985     0.1870                                             |=======
1986    -0.2212                                    =========|
1987    -0.3999                             ================|
1988     0.0731                                             |===
1989     0.2236                                             |=========
1990     0.0422                                             |==
1991    -0.1645                                      =======|
1992    -0.4230                            =================|
1993    -0.7578               ==============================|
1994     0.0000                                             |
1995     0.0000                                             |
1996     0.0000                                             |
1997     0.0000                                             |
1998     0.0000                                             |
1999     0.0000                                             |
2000     0.0000                                             |
2001     0.0000                                             |
2002     0.0000                                             |
                   -------------------------------------------------------------------------------------
```

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RESULTS OF BOOTSTRAPPED ANALYSIS

Param name	Bias-corrected estimate	Ordinary estimate	Relative bias	Approx 80% lower CL	Approx 80% upper CL	Approx 50% lower CL	Approx 50% upper CL	Inter-quartile range	Relative IQ range
B1ratio	1.755E+00	1.766E+00	0.62%	1.226E+00	2.464E+00	1.481E+00	2.099E+00	6.181E-01	0.352
K	5.154E+05	5.041E+05	-2.18%	4.122E+05	7.213E+05	4.568E+05	5.940E+05	1.372E+05	0.266
r	1.319E-01	1.366E-01	3.57%	7.870E-02	2.005E-01	1.003E-01	1.645E-01	6.419E-02	0.487
q(1)	6.571E-01	6.571E-01	0.00%	6.571E-01	6.571E-01	6.571E-01	6.571E-01	1.136E-10	0.000
q(2)	7.554E-06	8.001E-06	5.92%	6.327E-06	9.006E-06	6.815E-06	8.280E-06	1.465E-06	0.194
MSY	1.680E+04	1.722E+04	2.47%	1.338E+04	2.049E+04	1.506E+04	1.869E+04	3.623E+03	0.216
Ye(2003)	1.449E+04	1.466E+04	1.14%	8.352E+03	2.073E+04	1.089E+04	1.810E+04	7.209E+03	0.497
Bmsy	2.577E+05	2.521E+05	-2.18%	2.061E+05	3.607E+05	2.284E+05	2.970E+05	6.860E+04	0.266
Fmsy	6.596E-02	6.832E-02	3.57%	3.935E-02	1.002E-01	5.013E-02	8.223E-02	3.210E-02	0.487
fmsy(1)	1.004E-01	1.040E-01	3.57%	5.988E-02	1.525E-01	7.629E-02	1.251E-01	4.884E-02	0.487
fmsy(2)	8.634E+03	8.538E+03	-1.10%	5.895E+03	1.135E+04	7.163E+03	1.010E+04	2.935E+03	0.340
F(0.1)	5.936E-02	6.148E-02	3.21%	3.541E-02	9.021E-02	4.512E-02	7.400E-02	2.889E-02	0.487
Y(0.1)	1.664E+04	1.705E+04	2.45%	1.325E+04	2.029E+04	1.491E+04	1.850E+04	3.586E+03	0.216
B-ratio	6.153E-01	6.141E-01	-0.19%	3.695E-01	9.289E-01	4.755E-01	7.692E-01	2.937E-01	0.477
F-ratio	3.292E-01	3.283E-01	-0.26%	1.815E-01	6.560E-01	2.359E-01	4.744E-01	2.384E-01	0.724
Y-ratio	8.547E-01	8.511E-01	-0.42%	6.039E-01	9.890E-01	7.276E-01	9.444E-01	2.168E-01	0.254
f0.1(1)	9.034E-02	9.357E-02	3.21%	5.389E-02	1.373E-01	6.866E-02	1.126E-01	4.396E-02	0.487
f0.1(2)	7.770E+03	7.685E+03	-0.99%	5.305E+03	1.022E+04	6.447E+03	9.089E+03	2.642E+03	0.340
q2/q1	1.150E-05	1.218E-05	5.92%	9.629E-06	1.371E-05	1.037E-05	1.260E-05	2.229E-06	0.194

NOTES ON BOOTSTRAPPED ESTIMATES:

- The bootstrapped results shown were computed from 1000 trials.
- These results are conditional on the constraints placed upon MSY and r in the input file (ASPIC.INP).
- All bootstrapped intervals are approximate. The statistical literature recommends using at least 1000 trials for accurate 95% intervals. The 80% intervals used by ASPIC should require fewer trials for equivalent accuracy. Using at least 500 trials is recommended.
- The bias corrections used here are based on medians. This is an accepted statistical procedure, but may estimate nonzero bias for unbiased, skewed estimators.

Trials replaced for lack of convergence: 0
Trials replaced for MSY out-of-bounds: 1
Trials replaced for r out-of-bounds: 14
Residual-adjustment factor: 1.0426

Table 14: The 4 plus biomass (' 000 tons) summary table.

Year	XSA	ASPIC
1989	309111	280400
1990	261872	239500
1991	198712	174900
1992	139435	141200
1993	94879	110700
1994	81778	92810
1995	77013	91800
1996	66627	88410
1997	83444	92770
1998	97499	102200
1999	74389	112800
2000	94399	124100
2001	91895	133400
2002	111428	143800

Tab. 15a: red.srr file for the Mterm projections under the observed 1989-2002 productivity regime

```
5                 Nparams
5                 Geometric mean model
44.340            1999-2001 age 4 XSA geomean in millions
0.00000E+000
0.00000E+000
0
0.00000E+000
14    Ndata
0.3917      Residuals (1989-2002)
0.2225
-0.1961
-0.5230
1.1563
1.9380
0.1628
0.0086
0.0029
-0.1955
-0.0070
-0.2078
0.2148
1.3115
0                 No extra data
```

Tab. 15b: red.srr file for the Mterm projections under a low productity regime

```
5                  Nparams
5                  Geometric mean model
44.340             1999-2001 age 4 XSA geomean in millions
0.00000E+000
0.00000E+000
0
0.00000E+000
13    Ndata
0.3917       Residuals (1989-2001; 1993 and 1994 residuals given by the
1992/1995
0.2225                  geomean recruitment)
-0.1961
-0.5230
-0.0684
-0.0684
0.1628
0.0086
0.0029
-0.1955
-0.0070
-0.2078
0.2148
0                  No extra data
```

Table 15c : An explanation of the red.sen file input data. Exploitation pattern corresponding to 40% of 2002 F*statusquo* applied to an average 2000-2002 relative F at age from 2003 XSA. Average 2000-2002 mean weights at age in the catch and in the stock. Maturity from 1989-2002 survey abundanc at age.

Name	Value	C.V.	Name	Value	C.V.	Name	Value	C.V.	Name	Value	C.V.
Population at age in 2003			Exploitation pattern (H - Human consumption)			Exploitation pattern (D - Discards)			Exploitation pattern (I - Industrials)		
N4	44340	0.47	sH4	0.0040	0.00	sD4	0.00	0.00	sI4	0.00	0.00
N5	147738	0.47	sH5	0.0034	0.00	sD5	0.00	0.00	sI5	0.00	0.00
N6	44052	0.47	sH6	0.0057	0.00	sD6	0.00	0.00	sI6	0.00	0.00
N7	25835	0.22	sH7	0.0110	0.00	sD7	0.00	0.00	sI7	0.00	0.00
N8	28331	0.21	sH8	0.0204	0.00	sD8	0.00	0.00	sI8	0.00	0.00
N9	20090	0.20	sH9	0.0214	0.00	sD9	0.00	0.00	sI9	0.00	0.00
N10	21286	0.27	sH10	0.0167	0.00	sD10	0.00	0.00	sI10	0.00	0.00
N11	18912	0.24	sH11	0.0319	0.00	sD11	0.00	0.00	sI11	0.00	0.00
N12	16639	0.22	sH12	0.0444	0.00	sD12	0.00	0.00	sI12	0.00	0.00
N13	83032	0.19	sH13	0.0551	0.00	sD13	0.00	0.00	sI13	0.00	0.00
N14	2126	0.21	sH14	0.0861	0.00	sD14	0.00	0.00	sI14	0.00	0.00
N15	677	0.21	sH15	0.0611	0.00	sD15	0.00	0.00	sI15	0.00	0.00
N16	560	0.19	sH16	0.0366	0.00	sD16	0.00	0.00	sI16	0.00	0.00
N17	894	0.18	sH17	0.0292	0.00	sD17	0.00	0.00	sI17	0.00	0.00
N18	432	0.19	sH18	0.0155	0.00	sD18	0.00	0.00	sI18	0.00	0.00
N19	3275	0.19	sH19	0.0155	0.00	sD19	0.00	0.00	sI19	0.00	0.00
Stock weight at age			Catch weight at age (H - Human consumption)			Catch weight at age (D - Discards)			Catch weight at age (I - Industrials)		
WS4	0.098	0.00	WH4	0.093	0.00	WD4	0.00	0.00	WI4	0.00	0.00
WS5	0.140	0.00	WH5	0.143	0.00	WD5	0.00	0.00	WI5	0.00	0.00
WS6	0.184	0.00	WH6	0.198	0.00	WD6	0.00	0.00	WI6	0.00	0.00
WS7	0.236	0.00	WH7	0.250	0.00	WD7	0.00	0.00	WI7	0.00	0.00
WS8	0.289	0.00	WH8	0.304	0.00	WD8	0.00	0.00	WI8	0.00	0.00
WS9	0.327	0.00	WH9	0.348	0.00	WD9	0.00	0.00	WI9	0.00	0.00
WS10	0.355	0.00	WH10	0.379	0.00	WD10	0.00	0.00	WI10	0.00	0.00
WS11	0.392	0.00	WH11	0.436	0.00	WD11	0.00	0.00	WI11	0.00	0.00
WS12	0.476	0.00	WH12	0.488	0.00	WD12	0.00	0.00	WI12	0.00	0.00
WS13	0.599	0.00	WH13	0.597	0.00	WD13	0.00	0.00	WI13	0.00	0.00
WS14	0.595	0.00	WH14	0.594	0.00	WD14	0.00	0.00	WI14	0.00	0.00
WS15	0.586	0.00	WH15	0.582	0.00	WD15	0.00	0.00	WI15	0.00	0.00
WS16	0.656	0.00	WH16	0.643	0.00	WD16	0.00	0.00	WI16	0.00	0.00
WS17	0.692	0.00	WH17	0.697	0.00	WD17	0.00	0.00	WI17	0.00	0.00
WS18	0.790	0.00	WH18	0.808	0.00	WD18	0.00	0.00	WI18	0.00	0.00
WS19	0.836	0.00	WH19	0.863	0.00	WD19	0.00	0.00	WI19	0.00	0.00
Natural mortality at age			Maturity								
M4	0.1	0.00	MT4	0.000	0.00						
M5	0.1	0.00	MT5	0.005	0.00						
M6	0.1	0.00	MT6	0.022	0.00						
M7	0.1	0.00	MT7	0.067	0.00						
M8	0.1	0.00	MT8	0.127	0.00						
M9	0.1	0.00	MT9	0.174	0.00						
M10	0.1	0.00	MT10	0.221	0.00						
M11	0.1	0.00	MT11	0.320	0.00						
M12	0.1	0.00	MT12	0.391	0.00						
M13	0.1	0.00	MT13	0.455	0.00						
M14	0.1	0.00	MT14	0.488	0.00						
M15	0.1	0.00	MT15	0.507	0.00						
M16	0.1	0.00	MT16	0.586	0.00						
M17	0.1	0.00	MT17	0.589	0.00						
M18	0.1	0.00	MT18	0.607	0.00						
M19	0.1	0.00	MT19	0.727	0.00						
Natural mortality multiplier in year			Effort multiplier in year (H - Human consumption)								
K2002	1	0.0	HF2002	1.0	0.0						
K2003	1	0.0	HF2003	1.0	0.0						
K2004	1	0.0	HF2004	1.0	0.0						

Table 16a: Redfish 3M short term SSB probability profiles from 0.4Fstatusquo. Low and observed recruitment randomly resampled.

0.4 Fstatus quo low productivity regime
Year projection

2006	0.0177	0.0213	0.0248	0.0284	0.0319	**0.0355**	0.0390	0.0426	0.0461	0.0497	0.0532
5th %ile	36161	35833	35509	35189	34872	34552	34236	33923	33614	33308	33006
10th %ile	37300	36959	36639	36316	36005	35681	35366	35049	34716	34384	34075
20th %ile	38846	38492	38143	37801	37466	37134	36793	36456	36140	35810	35482
50th %ile	42343	41943	41549	41162	40786	**40410**	40050	39686	39326	38968	38614
95th %ile	50296	49815	49340	48871	48407	47946	47473	46995	46549	46108	45672

0.4 Fstatus quo observed productivity regime
Year projection

2006	0.0177	0.0213	0.0248	0.0284	0.0319	**0.0355**	0.0390	0.0426	0.0461	0.0497	0.0532
5th %ile	36164	35838	35516	35197	34875	34561	34251	33945	33651	33344	33048
10th %ile	37323	36998	36679	36350	36027	35711	35400	35081	34767	34452	34137
20th %ile	38857	38493	38144	37807	37473	37130	36793	36452	36137	35811	35483
50th %ile	42364	41964	41570	41186	40806	**40437**	40067	39705	39343	38983	38627
95th %ile	50320	49818	49344	48872	48407	47946	47472	46990	46544	46103	45667

Final assessment data year	2002
1st year for populations in Sen	2003
First SSB profile 3 years ahead	2006

Table 16b: Redfish 3M medium term SSB probability profiles from 0.4Fstatusquo. Low and observed recruitment randomly resampled.

0.4 Fstatus quo low productivity regime
Year projection

2012	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
5th %ile	67834	66006	64237	62541	60960	59400	57906	56468	55054	53690	52327
10th %ile	70275	68402	66560	64776	63049	61419	59825	58237	56749	55298	53903
20th %ile	73173	71196	69309	67502	65731	63996	62333	60725	59199	57711	56265
50th %ile	80388	78302	76309	74329	72397	**70537**	68726	66990	65287	63653	62051
95th %ile	100207	97685	95236	92856	90559	88323	86122	83980	81841	79821	77891

0.4 Fstatus quo observed productivity regime
Year projection

2012	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
5th %ile	72340	70474	68644	66907	65149	63460	61819	60387	58875	57402	55992
10th %ile	74949	72980	71148	69297	67571	65899	64106	62388	60877	59417	57948
20th %ile	79342	77383	75444	73620	71851	70077	68362	66674	65010	63437	61863
50th %ile	88557	86371	84304	82304	80260	**78350**	76462	74655	72884	71180	69531
95th %ile	115366	112762	110232	107771	105375	103047	100785	98585	96443	94558	92432

Final assessment data year	2002	
1st year for populations in Sen	2003	
First SSB profile 3 years ahead	2006	SSB 2006
Last SSB profile 10 years ahead	2012	SSB 2012

Table 17a: Redfish 3M SSB probability profiles for the next 10 years with 0.4Fstatus quo. Low and observed recruitment randomly resampl

0.4 Fstatus quo/low productivity regime

SSB

Year	5th %ile	10th %ile	20th %ile	50th %ile	95th %ile
2003	29642	31306	32900	36499	45540
2004	32202	33630	35184	38642	47051
2005	34552	35681	37134	40410	47946
2006	39740	41426	43027	46942	55577
2007	42718	44043	46013	49834	59301
2008	46880	48452	50560	54790	65724
2009	53101	55152	57569	62859	76879
2010	55933	58298	60706	66800	83270
2011	58879	61069	63924	70690	89898
2012	59400	61419	63996	**70537**	88323

0.4 Fstatus quo/observed productivity regime

SSB

Year	5th %ile	10th %ile	20th %ile	50th %ile	95th %ile
2003	29642	31306	32900	36499	45540
2004	32202	33630	35184	38642	47051
2005	34561	35711	37130	40437	47946
2006	39791	41610	43178	47053	55670
2007	43104	44592	46428	50436	59705
2008	47875	49462	51676	56070	67074
2009	54787	56754	59396	65273	79828
2010	58416	60597	63596	70543	88016
2011	62101	64362	68159	76260	98821
2012	63460	65899	70077	**78350**	103047

Table 17b: Redfish 3M yield probability profiles for the next 10 years with 0.4Fstatus quo. Low and observed recruitment randomly resample

0.4 Fstatus quo/low productivity regime

Year	5th %ile	10th %ile	20th %ile	50th %ile	95th %ile
2003	3226	3392	3570	**3971**	4993
2004	4233	4451	4684	**5223**	6549
2005	3849	4002	4170	**4579**	5454
2006	3664	3807	3978	4322	5185
2007	3618	3745	3888	4222	5118
2008	3363	3465	3585	3864	4618
2009	3601	3759	3926	4376	5563
2010	3765	3928	4152	4766	6290
2011	3966	4176	4485	5213	7264
2012	4165	4402	4754	5590	8142

0.4 Fstatus quo/observed productivity regime

Year	5th %ile	10th %ile	20th %ile	50th %ile	95th %ile
2003	3226	3392	3570	**3971**	4993
2004	4238	4462	4703	**5228**	6561
2005	3895	4022	4210	**4595**	5476
2006	3705	3867	4019	4378	5243
2007	3704	3853	3994	4333	5275
2008	3474	3599	3754	4103	5093
2009	3801	3960	4198	4739	6244
2010	4035	4232	4545	5220	7052
2011	4339	4656	5025	5885	8305
2012	4680	5037	5484	6509	9681

Tab. 18: SSB and yield 50th %ile profiles for 0.4 Fstatusquo/observed productivity regime versus low productivity re

SSB

Year	50th %ile observed	50th %ile low
2003	36499	36499
2004	38642	38642
2005	40437	40410
2006	47053	46942
2007	50436	49834
2008	56070	54790
2009	65273	62859
2010	70543	66800
2011	76260	70690
2012	78350	70537

Yield

Year	50th %ile observed	50th %ile low
2003	3971	3971
2004	5228	5223
2005	4595	4579
2006	4378	4322
2007	4333	4222
2008	4103	3864
2009	4739	4376
2010	5220	4766
2011	5885	5213
2012	6509	5590

Table 19: SSB and yield Mtprojections from 2001 and 2002 under a low productivity regime. For 2002 and 2003 projectio
short term yield was kept between the most recent level of catches and the actual TAC(5000tons).

SSB 50th %ile profiles

Year	40%F2002	60%F2001
2003	36499	44088
2004	38642	46312
2005	40410	46893
2006	46942	52257
2007	49834	54993
2008	54790	57203
2009	62859	64733
2010	66800	65980
2011	70690	67143
2012	**70537**	

Yield 50th %ile profiles

Year	40%F2002	60%F2001
2003	**3971**	**5142**
2004	**5223**	**4764**
2005	**4579**	**3703**
2006	4322	4771
2007	4222	3805
2008	3864	3754
2009	4376	3942
2010	4766	3943
2011	5213	4094
2012	5590	

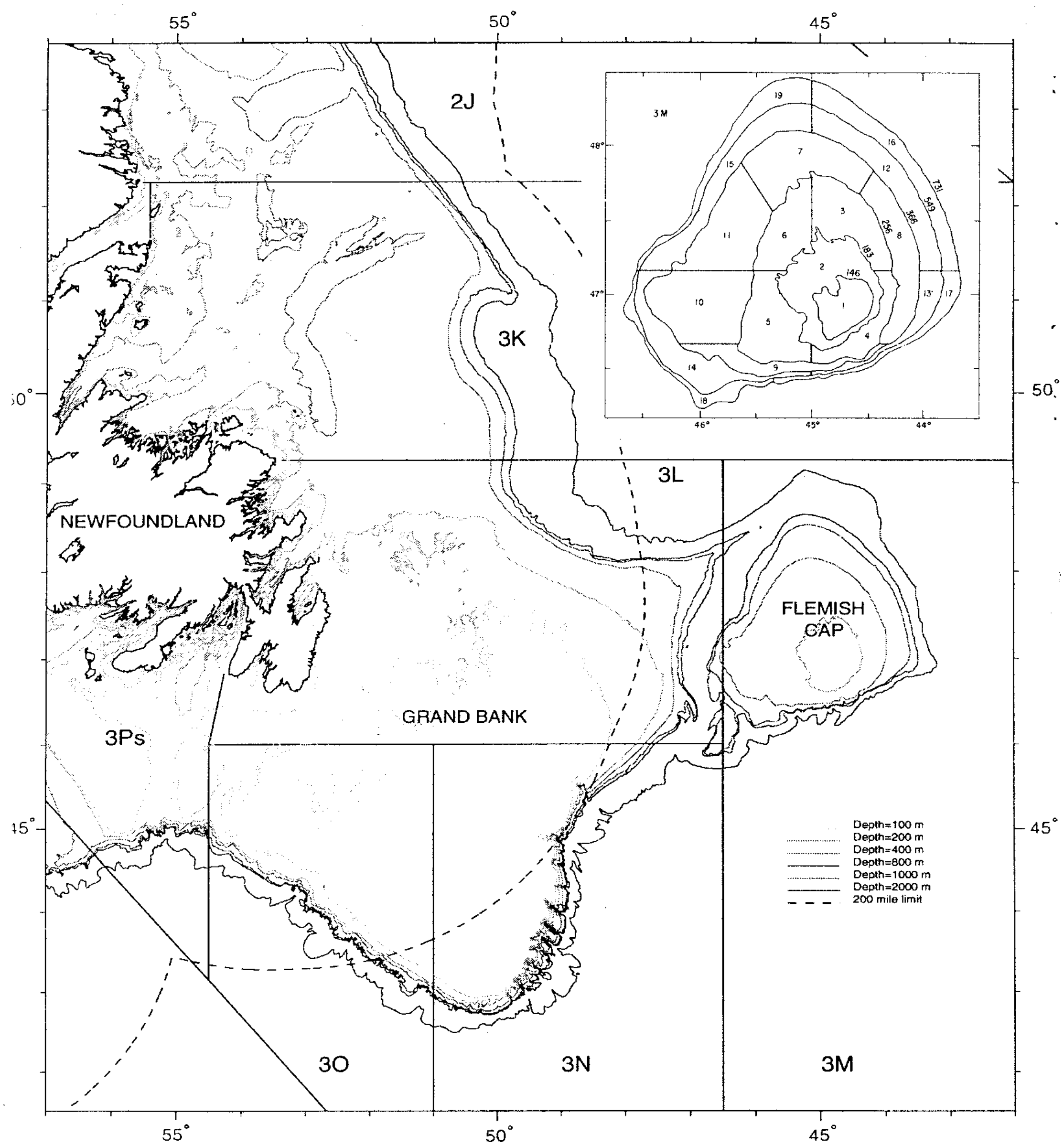


Fig.1a: Map showing the location of Flemish Cap (Div. 3M) in the Northwest Atlantic. The insert is the depth stratification scheme (m) used in the past Canadian bottom trawl survey in Flemish Cap, as well as in the present European Union (EU) survey series.

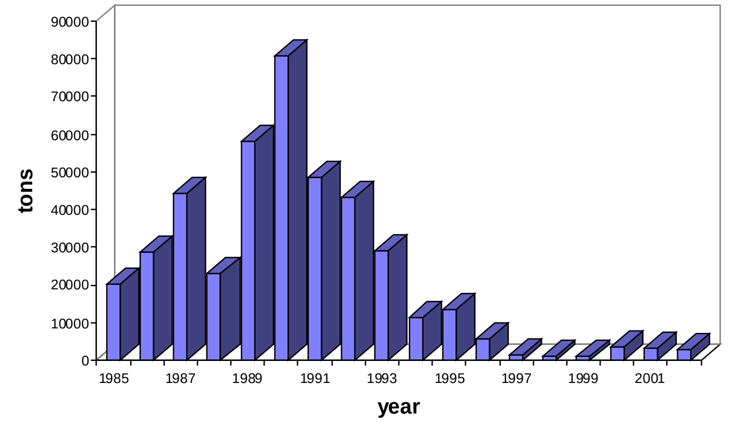


Fig. 2a: STACFIS estimate of commercial catches

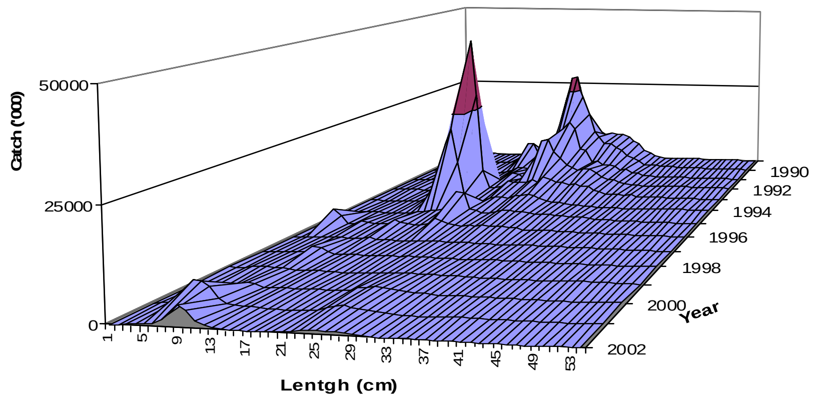


Fig. 2b: Catch in numbers at length (1989-2002), including bycatch (1993-2002)

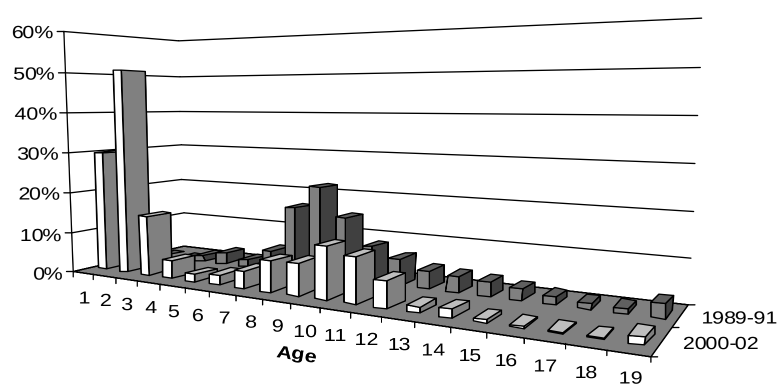


Fig.3: Relative catch at age: 1989-1991 vs 2000-2002

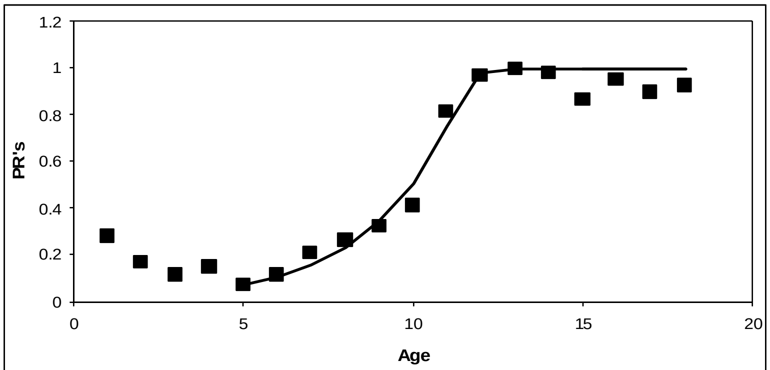


Fig. 4: PR curve for 3M beaked redfish

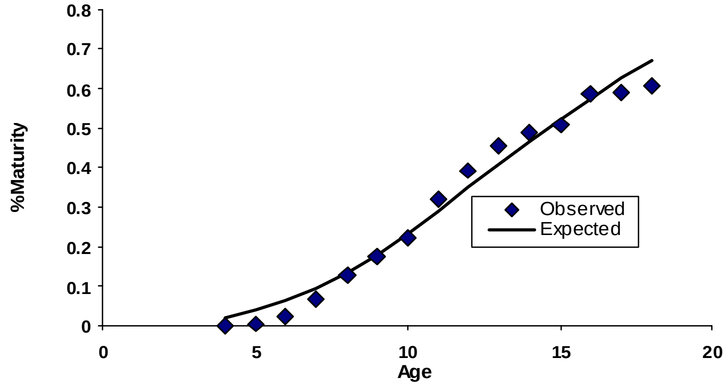


Fig. 5: Maturity ogive for 3M beaked redfish

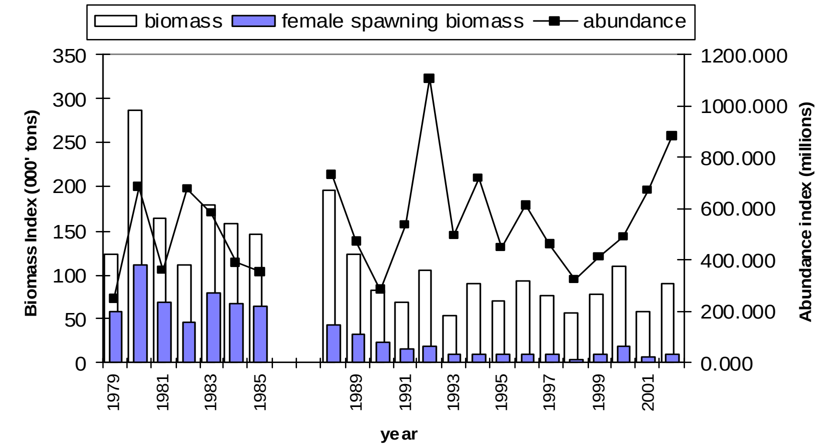


Fig. 6a: 3M Beaked redfish biomass, female spawning biomass and abundance (Canada survey, 1979/1985; EU survey, 1988/2002)

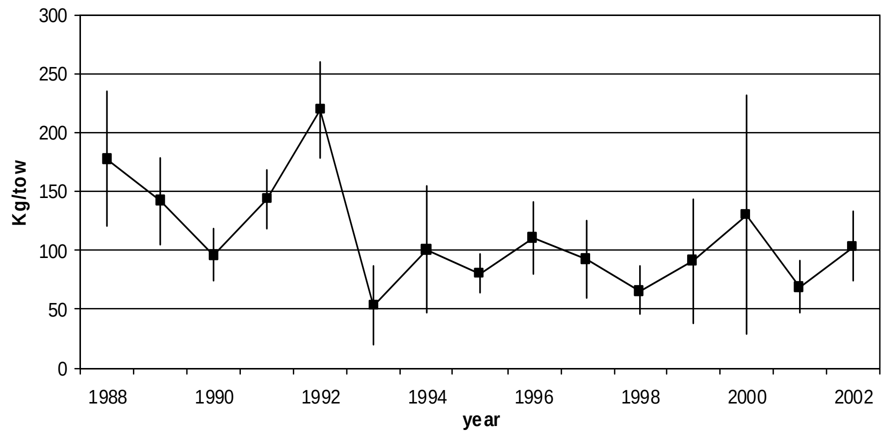


Fig. 6b: mean catch per tow for 3M beaked refish (EU survey, 1988-2002) with associated +/- 2se

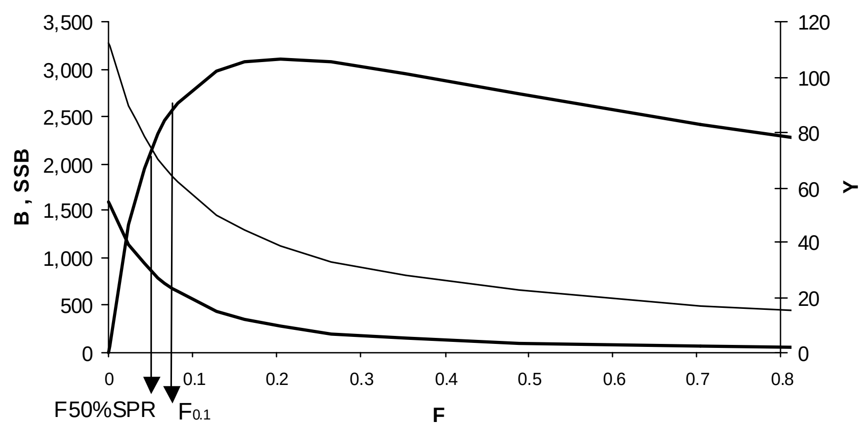


Fig 7: Yield, SSB and B per recruit curve for 3M redfish.

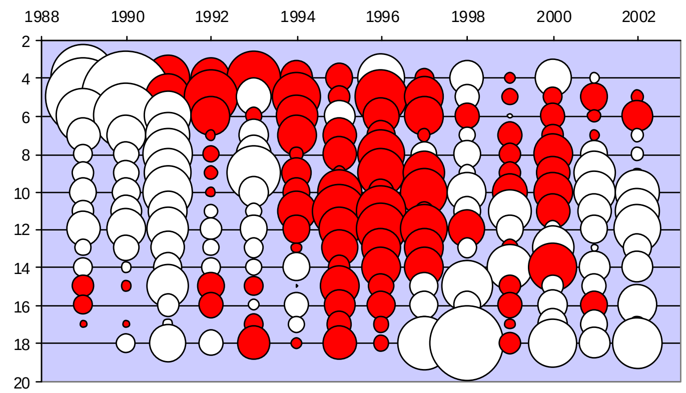


Fig. 8a: Eu survey log q residuals

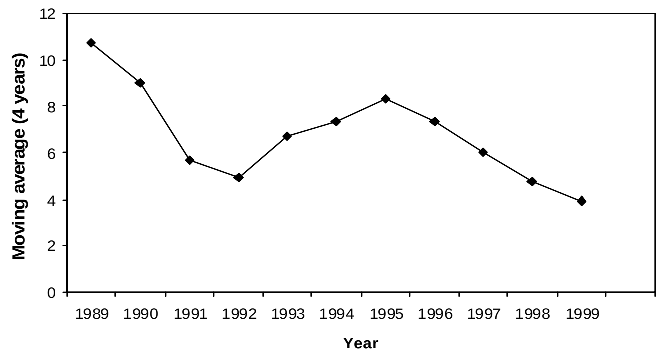


Fig 8b: moving average of annual SS log catchability residuals from XSA

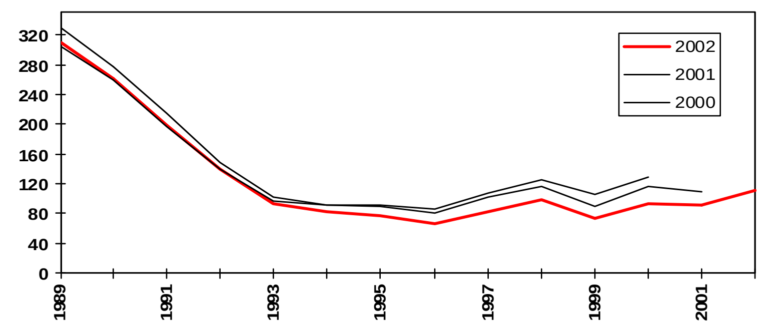


Fig. 9a: Biomass (thousand tons)

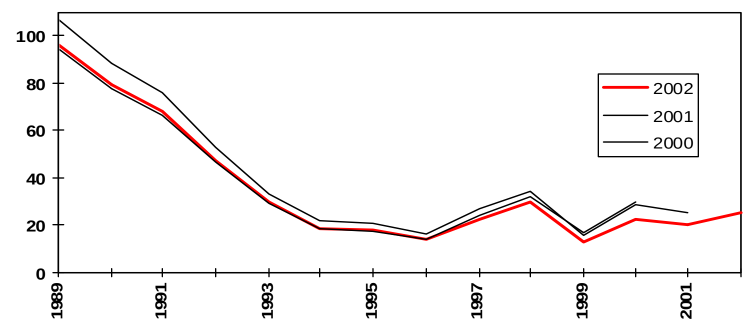


Fig. 9b: SSB (thousand tons)

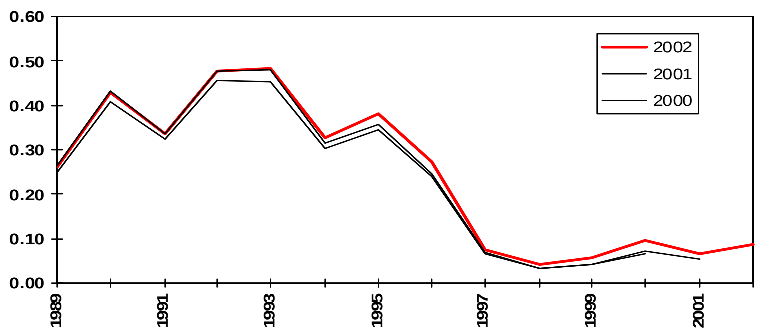


Fig. 9c: Mean F

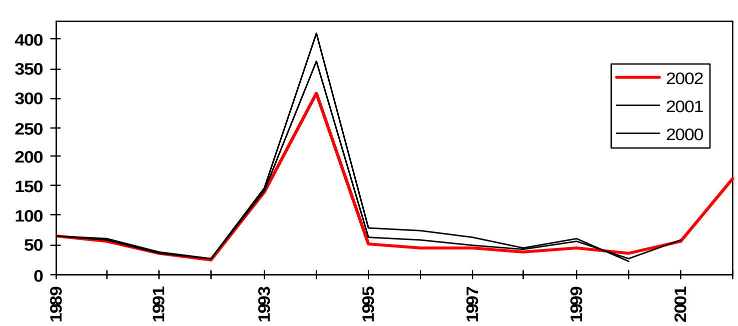


Fig. 9d: Recruitment (millions - age 4)

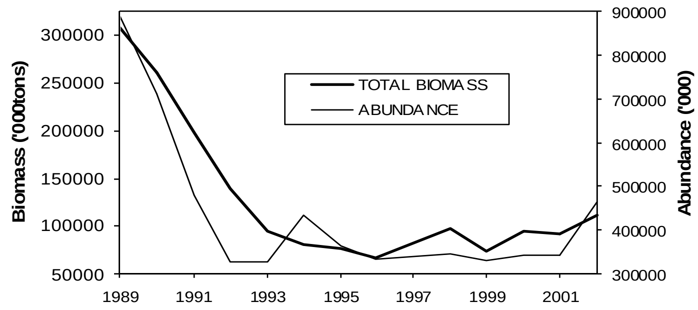


Fig. 10a: 4+Biomass vs 4+Abundance from XSA

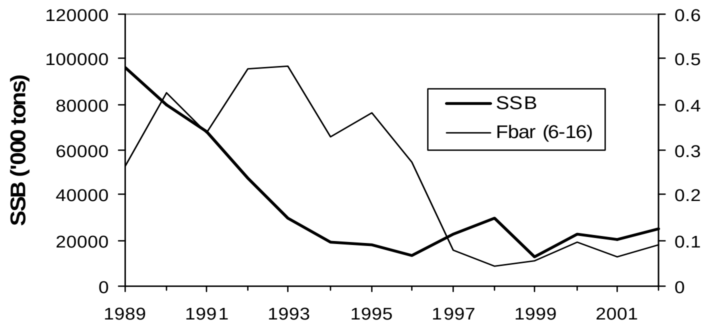


Fig. 10b: SSB vs FBar from XSA

Fig. 10c: Recruitment/SSB from XSA

recruits at age 4 four years later

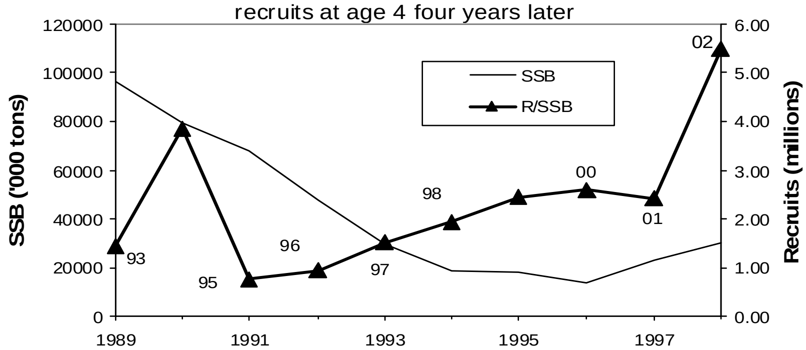
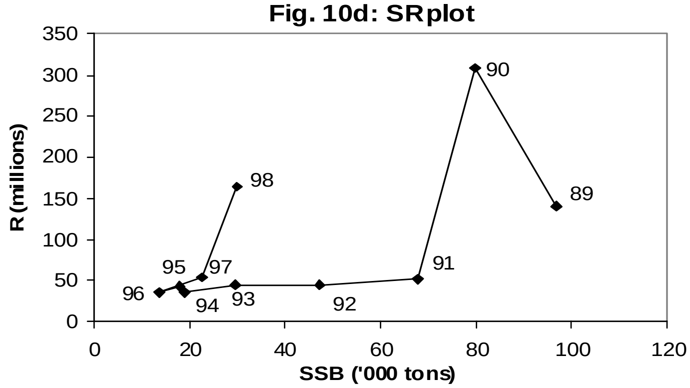


Fig. 10d: SRplot



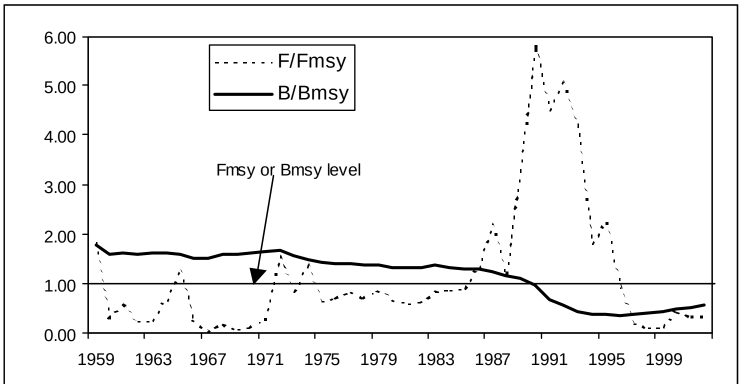


Fig. 11a: Fishing mortality and stock biomass trends from ASPIC presented as Fmsy and Bmsy ratios

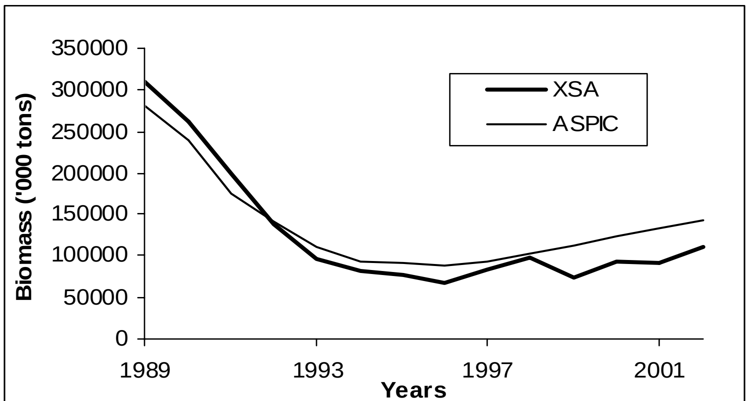


Fig. 11b: 3M beaked redfish 4plus biomass

Fig. 12a. SSB 2006 under a low productivity regime

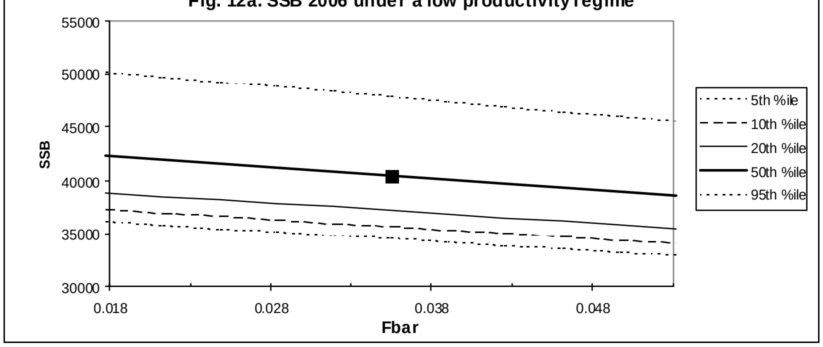
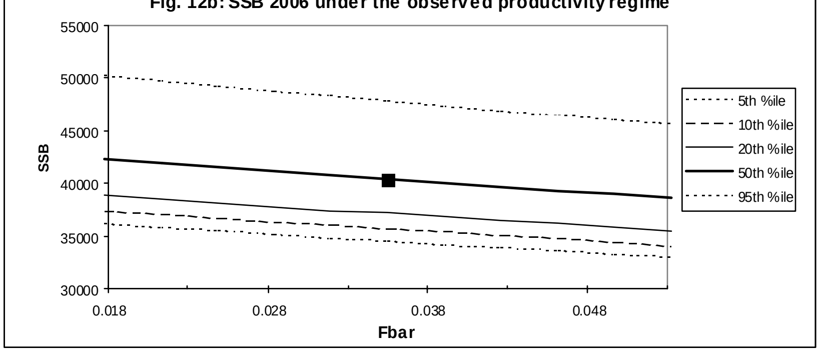


Fig. 12b: SSB 2006 under the observed productivity regime



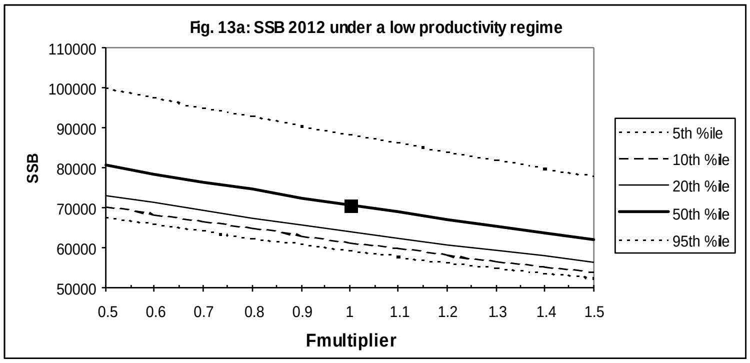


Fig. 13a: SSB 2012 under a low productivity regime

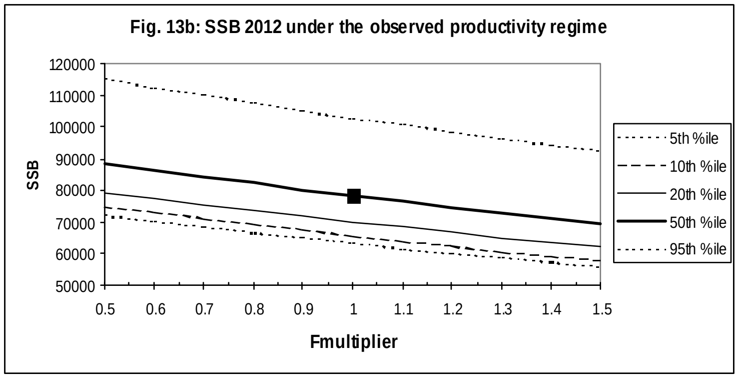


Fig. 13b: SSB 2012 under the observed productivity regime

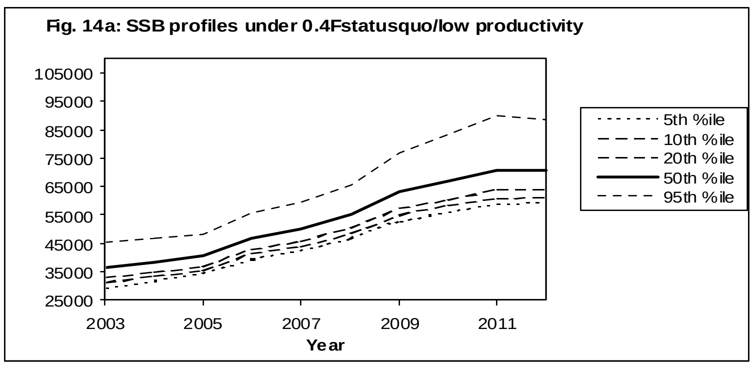


Fig. 14a: SSB profiles under 0.4Fstatusquo/low productivity

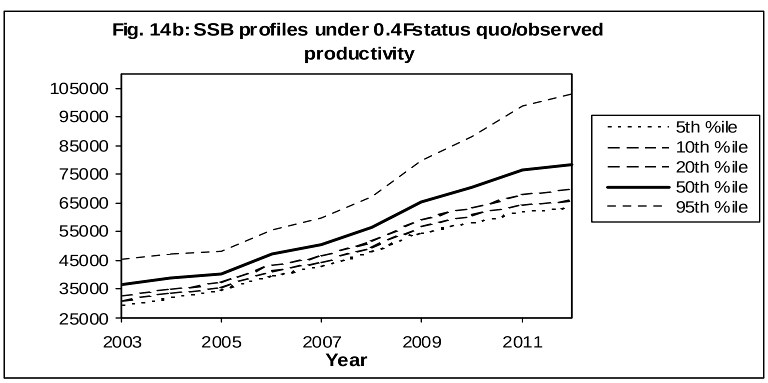


Fig. 14b: SSB profiles under 0.4Fstatus quo/observed productivity

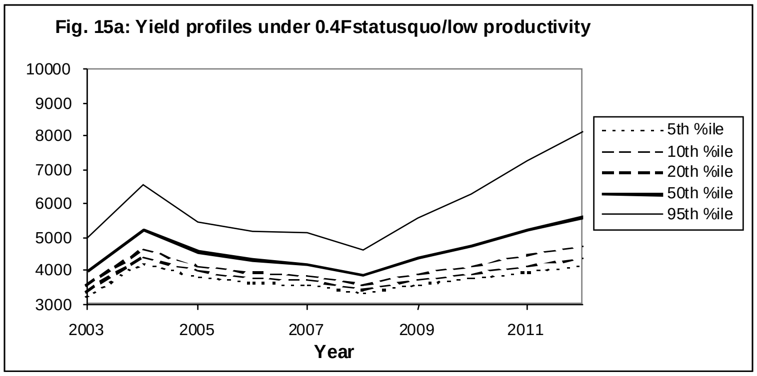


Fig. 15a: Yield profiles under 0.4Fstatusquo/low productivity

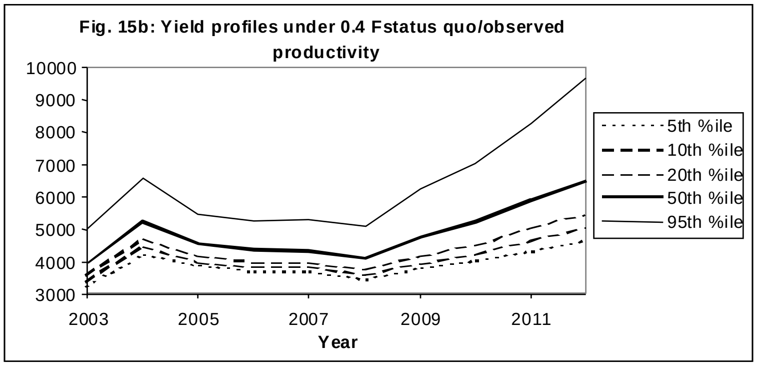


Fig. 15b: Yield profiles under 0.4 Fstatus quo/observed productivity

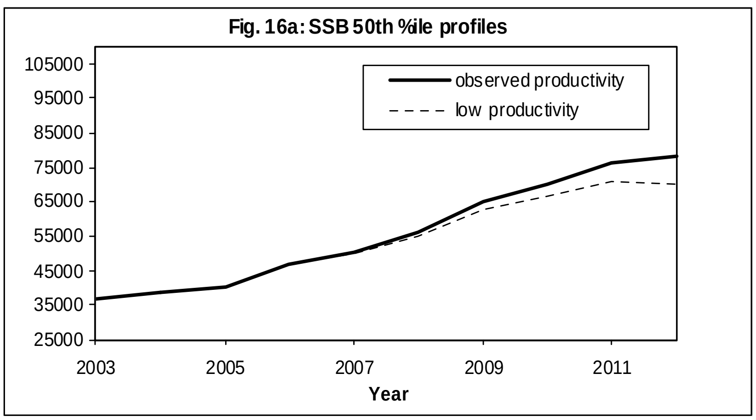


Fig. 16a: SSB 50th %ile profiles

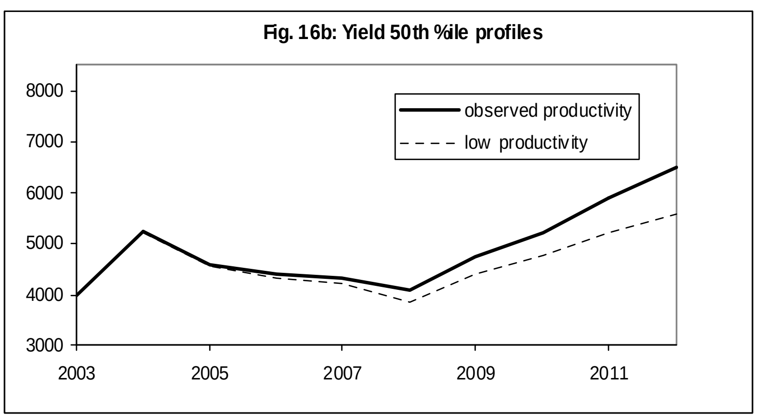


Fig. 16b: Yield 50th %ile profiles

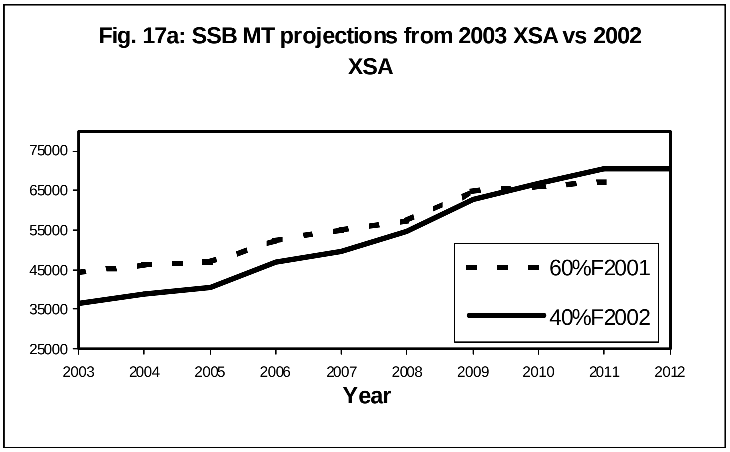


Fig. 17a: SSB MT projections from 2003 XSA vs 2002 XSA
75000
65000
55000
45000
35000
25000
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Year
60%F2001
40%F2002

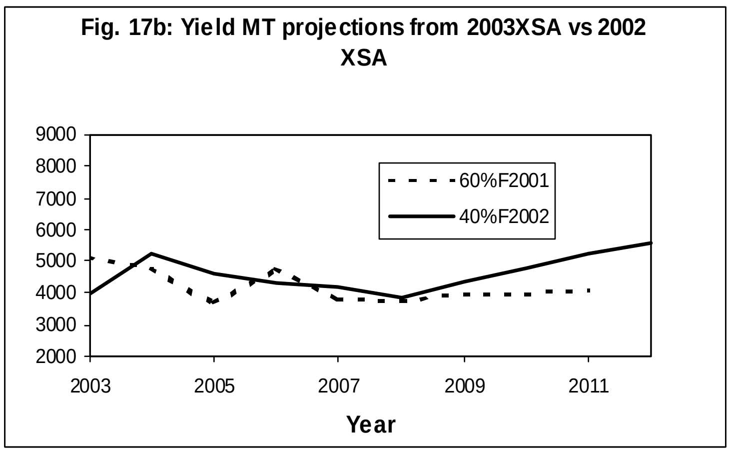


Fig. 17b: Yield MT projections from 2003XSA vs 2002 XSA
9000
8000
7000
6000
5000
4000
3000
2000
2003
2005
2007
2009
2011
Year
60%F2001
40%F2002