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Northwest Atlantic Fisheries Organization

**Serial No. N5923** **NAFO SCR Doc. 11/38**

SCIENTIFIC COUNCIL MEETING – JUNE 2011

# Assessment of the Cod Stock in NAFO Division 3M

by

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**Abstract**

An assessment of the cod stock in NAFO Division 3M is performed. A Bayesian model, as used in the last assessments, was used to perform the analysis. Results indicate a fairly substantial increase in SSB, reaching a value well above $B_{lim}$. The six-years retrospective plot shows that the recruitment is overestimated every year. Three year projections indicate that fishing at the $F_{statusquo}$ level should allow SSB to increase slowly, although abundance will remain at levels below those observed at the beginning of the series. If the fishing mortality were return to the levels seen before 1995, stock recovery would become improbable.

## Introduction

This stock had been on fishing moratorium since 1999 to 2009 following its collapse, which has been attributed to three simultaneous circumstances: a stock decline due to overfishing, an increase in catchability at low abundance levels and a series of very poor recruitments starting in 1993. The assessments performed since the collapse of the stock confirmed the poor situation, with SSB at very low levels, well below $B_{lim}$ (Vázquez and Cerviño, 2005). Nevertheless, Spawning Stock Biomass (SSB) was estimated to increase a bit in 2004, 2005 and 2006 (Fernández, *et al.*, 2007) and above average recruitment levels were estimated for 2005 and 2006. Another large increase in SSB in 2007-2009, largely due to the recruitments in 2005-2006, has happened, reaching in 2009 the second highest values of the studied series (González-Troncoso and Vázquez, 2010).

Since 1974, when a TAC was established for the first time, estimated catches ranged from 48000 tons in 1989 to a minimum value of 5 tons in 2004. Annual catches were about 30000 tons in the late 1980's (notwithstanding the fact that the fishery was under moratorium in 1988-1990) and diminished since then as a consequence of the stock decline. Since 1998 yearly catches have been less than 1000 tons and from 2000 to 2005 they were under 100 tons, mainly attributed to by-catches from other fisheries. Estimated commercial catches in 2006, 2007, 2008 and 2009 are 339, 345, 889 and 1161 tons (Table 1 and Figure 1), respectively, which represent more than a ten-fold increase over the average yearly catch during the period 2000-2005. The results of the 2009 assessment led to a reopening of the fishery with 5500 tons of catch in 2010. The estimated catch for 2010 is 9291 tons, which almost double the TAC.

A VPA based assessment of the cod stock in Flemish Cap was approved by NAFO Scientific Council (SC) in 1999 for the first time and was annually updated until 2002. However, most recent catches were very small undermining the VPA based assessment, as its results are quite sensitive to assumed natural mortality when catches are at low levels. Cerviño and Vázquez (2003) developed a method which combines survey abundance indices at age with catchability at age, the latter estimated from the last reliable accepted XSA. The method estimates abundances at age with their associated uncertainty and allows calculating the SSB distribution and, hence, the probability that SSB is above or below any reference value. The method has been used to assess the stock since 2003. In 2007 results from an alternative Bayesian model were also presented (Fernández *et al.*, 2007) and in 2008 this Bayesian model was further developed and approved by the NAFO SC (Fernández *et al.*, 2008).

An assessment of this stock using the Bayesian model used last years is presented. A $B_{lim}$ of 14000 tons was proposed by the NAFO Scientific Council in 2000. The appropriateness of this value given the results from the new method used to assess the stock was examined in 2008, concluding that it is still an appropriate reference.

## Material and Methods

## Used data

### Commercial data

#### Length distributions

In 2010 length sampling of catch was conducted by Lithuania (Statkus, 2011), Norway (pers. com.), Portugal (Vargas *et al.*, 2010), Spain (González-Costas *et al.*, 2010) and UK (pers. com.). Length frequency distributions from the commercial catch and from the EU survey (Casas and González-Troncoso, 2011) are shown in Figure 2.

Lithuania has measured 200 individuals in one single sample. This length distribution has a clear mode at 60 cm. with a range of 34-86 cm, but it was not considered representative of the whole catch due to the small size sample. Norway has 12 samples with a total of 3902 individuals measured. Of these, 2 samples were from a trawl vessel (507 individuals) and 8 from a twin trawl vessel (3395 individuals). As the split catches for the two gears are no available, both length distributions were added, as a plot shows that there are no differences between them. The range of the distribution is from 23 to 119 cm, with a mode in 57 cm. The length distribution of Portugal is made from 182 samples with 17658 individuals measured. The range of lengths is 18-111 cm. The mode is in 54 cm. Spain provided the data from 34 samples and 8445 individuals measured. The range of the distribution is 35-115 cm and it has a mode in 54 cm. 24 samples are available from UK, with a total of 2678 individuals measured. The range is 42-132 cm, with a not well-defined mode between 90 and 105 cm. The EU survey has a well-defined mode around 18 cm, following with another mode in 33 cm and two more, weaker, around 48 and 57 cm. The range is from 12 to 117 cm.

The Portuguese length distribution starts in 18 cm, the Spanish one in 35 cm and the UK one in 42 cm, with the highest percentage of highest lengths with a mode around 100 cm. The EU survey has a great presence of individuals of around 18 cm.

#### Catch-at-age

Catch-at-age is presented in Table 2. As no age-length keys (ALK) were available for commercial catch from 1988 to 2008, each year the corresponding ALKs from the EU survey were applied in order to calculate annual catch-at-age. A commercial ALK was available for 2009 for the Portuguese commercial data and was applied to the total commercial length distribution. For 2010, two ALKs were available, one for the Portuguese data from the same reader as last years for commercial data and for survey data, and another one for the commercial Spanish data from a new reader. It was observed some differences between both ALKs, as we can see in Figure 3, in which mean length per age is presented for both ALKs. In order to maintain the consistency of the series, it was decided to use the Portuguese ALK for all the commercial catch because comes from the same reader as the previous years for commercial and EU survey data.

The range of ages in the catch goes from 1 to 8+. No catch-at-age was available for 2002-2005 due to the lack of length distribution information because of low catches.

Figure 4 shows a bubble plot of catch proportions at age over time (with larger bubbles corresponding to larger values), indicating that the bulk of the catch (including 2010 catch) is comprised of 3-5 years age cod. In years 2006 and 2009, catches containing mostly age 4 individuals. In 2007 there has been much more spread over the ages, and in 2008 the greatest presence was ages 2 to 4.

Figure 5 shows standardised catch proportions at age (each age standardised independently to have zero mean and standard deviation 1 over the range of years considered). Assuming that the selection pattern at age is not too variable over time, it should be possible to follow cohorts from such figure. Some strong and weak cohorts can be followed, although the pattern is not too evident. It is remarkable the recruitment (age 1) in the year 2010, that is the highest positive value in the series.

Mean weight-at-age

Mean weight-at-age has been computed separately for the catch and for the stock, using length-weight relationships from the Portuguese commercial sampling and from the EU survey, respectively. Both are presenting in Figure 6. The commercial weights are smaller than those from the EU survey. The Portuguese length-weight relationship was applied to the commercial data to calculate weight-at-age in the catch. Results are showed in Table 4.

The SOP (sum over ages of the product of catch weight-at-age and numbers at age) for the commercial catch only differs in 1.7% from the estimated total catch.

## Survey data

The EU bottom trawl survey of Flemish Cap has been carried out since 1988, targeting the main commercial species down to 730 m of depth. The surveyed zone includes the complete distribution area for cod, which rarely occurs deeper than 500 m. The survey procedures have been kept constant throughout the entire period, although in 1989 and 1990 a different research vessel was used. Since 2003, the survey has been carried out with a new research vessel (R/V *Vizconde de Eza*, replacing R/V *Cornide de Saavedra*) and conversion factors to transform the values from the years before 2003 have been implemented (González- Troncoso and Casas, 2005).

The results of the survey for the years 1988-2010 are present in Casas and González-Troncoso, 2011.

Survey indices of abundance at age are presented in Table 3. Figure 7 displays the estimated biomass and abundance indices over time. Biomass and abundance show a high increase since 2005, higher in biomass than in abundance, following an extremely low period starting in the mid 1990's. It must be noted that 2009 biomass is at the level of the first years of the assessment but abundance is roughly the same as in 1994. In 2010 the biomass has suffered a bit decrease, probably due to the opening of the fishery, but it is still at the level of the first year assessment biomass. The abundance has had a marked increase due to the incoming recruitment. Figure 8 shows a bubble plot of the abundances at age, in logarithmic scale, with each age standardised separately (each age to have mean 0 and standard deviation 1 over the range of survey years). Grey and black bubbles indicate values above and below average, respectively, with larger sized bubbles corresponding to larger magnitudes. The plot indicates that the survey is able to detect strength of recruitment and to track cohorts through time very well. It clearly shows a series of consecutive recruitment failures from 1996 to 2004, leading to very weak cohorts. Cohorts recruited from 2005 onwards appear to be above average.

Mean weight-at-age in the stock shows a strong increasing trend since the late 1990's, although in 2008 all the ages decreased their mean weight-at-age, but still remain higher than at the beginning of the series. In 2009 youngest and oldest ages increased theirs mean weight-at-age with respect to 2008, while the ages 3-4 decreased them (see Table 5 and Figure 9). In 2010 all ages except 3 and 7 decreased their mean weight-at-age with respect to 2009, reaching more or less the level of the 2008 values.

## Maturity at age

Maturity ogives from the EU survey are available for years 1990-1998, 2001-2006 and 2008-2010. For those years logistic regression models for proportion mature at age have been fitted independently for each year. For 1988 and 1989 the 1990 maturity ogive was applied. For 1999 and 2000 maturity ogive was computed as a mixture of 1998 and 2001 data, and for 2007 as a mixed of 2006 and 2008 maturity ogive. Maturity data for 1991 were of poor quality and did not allow a good fit, so a mixture of the ogives for 1990 and 1992 was used. The median of the maturity ogives for the whole period are presented in the Table 6.

Figure 10 displays the evolution of the a50 (age at which 50% of fish are mature) through the years (estimate and 90% uncertainty limits). The figure shows a continuous decline of the a50 through time, from above 5 years old in the late 1980's to just above 3 years old since about 2000. Since 2005 the a50 has increased slowly, reaching 3.5 years in 2010.

## Assessment methodology

The Bayesian model used last years was updated with 2010 data. For years with catch-at-age data, it works starting from cohort survivors and reconstructing cohorts backwards in time using catch-at-age and the assumed mortality rate. When catch-at-age is not available for a year but an estimate of total catch in weight is available, this information can be incorporated in the model by means of an observation equation relating (stochastically) the estimated catch weight to the underlying population abundances (hence aiding in the estimation of fishing mortalities). An advantage of the model is that it allows combining years with catch-at-age and years where only total catch is available. Years with no information on commercial catch are also allowed. A detailed description of the model is in Fernandez *et al.*, 2008. The priors were chosen this year as last assessment. The inputs of the assessment of this year are as follow:

**Catch data** for 23 years, from 1988 to 2010

Years with catch-at-age: 1988-2001, 2006-2010

**Tuning** with EU survey for 1988 to 2010

**Ages** from 1 to 8+ in both cases

**Catchability analysis**

Catchability dependent on stock size for ages 1 and 2

**Priors** over parameters:

Priors over the survivors:

For (2010, a), a=1,…,7 and (y, 7), y=1988,…,2009

$$surv(y,a) \sim LN\left( median = medrec \times e^{-medM - \sum_{age=1}^{a} medFsurv(age)}, cv = cvsurv \right),$$

*where* medrec=15000

medFsurv(1,…,7)={0.0001, 0.1, 0.5, 0.7, 0.7, 0.7, 0.7}

cvsurv=1

Prior over F for years with no catch-at-age:

For a=1,…,7 and y=2002,…,2005

$$F(y,a) \sim LN\left(median = medF(a),\ cv = cvF\right)$$

*where* medF=c(0.0001, 0.005, 0.01, 0.01, 0.01, 0.005, 0.005)

cvsurv=0.7

Prior over the total catch in the years with no catch-at-age data:

For y=2002,…,2005

$$CW(y) \sim LN\left(median = CW_{\mathrm{mod}}(y),\ cv = cvCW\right)$$

*where* $CW_{mod}$ is arised from the Baranov equation

cvCW=0.05

Prior over the EU survey abundance at age indices:

For a=1,…,8 and y=1988,…,2010

$$I(y) \sim LN\left( median = \mu(y,a),\ cv = \sqrt{e^{\frac{1}{\psi(a)}} - 1} \right)$$

$$\mu(y,a) = q(a)\left( N(y,a)\frac{e^{-\alpha Z(y,a)} - e^{-\beta Z(y,a)}}{(\beta - \alpha)Z(y,a)} \right)^{\gamma(a)}$$

$$\gamma(a)\begin{cases} \sim N(\text{mean} = 1, \text{variance} = 0.25),\ if\ a = 1,2 \\ = 1,\ if\ a \geq 3 \end{cases}$$

$$\log(q(a)) \sim N(\text{mean} = 0, \text{variance} = 5)$$

$$\psi(a) \sim gamma(shape = 2, rate = 0.07)$$

*where* I is the EU survey abundance index

q is the survey catchability at age

N is the commercial abundance index

$\alpha = 0.5$, $\beta = 0.58$ (survey made in July)

Z is the total mortality

Prior over natural mortality, M:

$$M \sim LN(\text{median} = 0.218, cv = 0.3)$$

In 2008 STACFIS recommended *that retrospective analysis be performed as a standard diagnostic of the assessment with the Bayesian model*. So, six year retrospective plot was made.

Three years projections were made with six different scenarios, as later described, in order to see the possible evolution of the stock. The settings and the results are explained above.

## Results

Assessment results regarding to total biomass, SSB, recruitment and $F_{bar}$ (ages 3-5) are presented in Table 7 and Figure 11. The SSB graph also includes the expected value at the beginning of the year 2011. To calculate it, weight-at-age and maturity-at-age random draws from the three last years with data were used (assuming always that maturity at age 1 is equal to 0, as there is no estimate of recruitment in 2011). The results indicate that there has been a substantial increase in SSB in the last few years, with the largest increase occurring from 2007 onwards. SSB in 2009 (and even its confidence intervals) are well above $B_{lim}$, and in 2010 is the highest value of the time series, very close to 1989 SSB. The SSB at the beginning of 2011 is even expected above this value, although the uncertainty associated with this value is very high.

It must be noted that, although SSB is in 2010 at the level of the beginning of the time series, total biomass and abundance are at the level of the year 1994 due to age of first maturity has been reduced.

Recruitment in 2005-2010 have been above the mean of the period, although the actual recruitment levels for these years can not yet be precisely estimated (wide uncertainty limits in Figure 11 and Table 7). 2010 recruitment is at the level of the first years assessment, only below the two strong year classes of 1990 and 1991.

$F_{bar}$ (mean for ages 3-5) has been at very low levels in the period 2001-2009 (Figure 11), although an unusual high value has been estimated for 2006. In 2010, when the fishery was reopen, the $F_{bar}$ has increased up to 0.27, although the 5500 tons TAC corresponded to a target $F_{bar}$ around 0.14 was established. Table 8 and Figure 13 provide more detailed information on the estimated F-at-age values, indicating that the increase in $F_{bar}$ in 2006 is mostly due to fishing mortality at age 3. In 2008 the highest fishing mortalities are in ages 5 and 6, in 2009 in ages 7 and 8+ and in 2010 in ages 4 and 6.

Figure 12 shows total biomass and abundance by year. Except in the first years of the assessment, there is a good concordance between numbers and weight, although in last years biomass has increased more than abundance. The projection for the year 2011 indicates a new increase in total biomass but a decrease in abundance.

Estimates of stock abundance at age for 1988-2011 are presented in Table 9 and Figure 14. Abundance at age in 2011 are the survivors of the same cohort in 2010, the last assessment year, so only abundances of ages older than age 1 can be estimated.

Figure 15 depicts the prior and posterior distributions of survivors at age at the end of the final assessment year, where by survivors(2010, a) it is meant individuals of age a + 1 at the beginning of 2011 (in other words, survivors(2010, a) = N(2011, a + 1)). The plotting range for the horizontal axis is the 95% prior credible interval in all cases, to facilitate comparison between prior and posterior distributions; the same procedure will be followed in all subsequent prior-posterior plots. There has been very substantial updating of the prior distribution for survivors of ages 4 and older. This is no the case for younger ages, with prior and posterior distributions being much closer; this behaviour was expected as few ages of these cohorts have been observed to date.

Figure 16 displays prior and posterior distributions for survivors of the last true age at the end of every year. By survivors(y, 7) it is meant individuals of age 8 (not 8+) at the beginning of year y + 1. Whereas the prior distribution is the same every year, posterior distributions vary substantially depending on the year, displaying particularly low values between 2002 and 2005 and in years 2008 and 2010.

Bubble plot of raw residuals (observed minus fitted values) for the EU survey abundance indices at age (in logarithmic scale) is presented in Figure 17. No obvious trends over time or any other particular patterns emerge from the residuals plot.

Bubble plot of standardised residuals (observed minus fitted values divided by estimated standard deviations and in logarithmic scale) for the EU survey abundance at age indices is displayed in Figure 18. As the residuals have been standardised, they should be mostly in the range (—2, 2) if model assumptions about variance are not contradicted by the data. This graph should highlight year effects, identified as years in which most of the residuals are above or below zero. In 1988 all residuals are negative except for the one for age 7, whereas the opposite happens in 1996 and 1997, suggesting year effects (i.e. survey catchabilities that are below average in 1988 and above average in 1996 and 1997). All residuals were positive in 2008-2010 except for ages 1 in 2008, 1 and 2 in 2009 and 5 and 7 (this last value is almost 0) in 2010.

Figure 19 shows the parameter $\log(\varphi(a))$, which corresponds to log(catchability) of the EU survey's for ages $a \geq 3$. For ages a = 1, 2 catchability depends also on stock abundance and this dependence is regulated via the parameter $\gamma(a)$, for which results are in Figure 20. The posterior probability that $\gamma(a) > 1$ for a = 1, 2 is very high, pointing towards an increase in survey catchabilities for the younger ages that occurs when abundance of those ages increases.

## Biological Referent Points

Figure 21a shows a SSB-Recruitment plot and Figure 21b a SSB-$F_{bar}$ plot, both with the 14 000 value of $B_{lim}$ indicated with a vertical red line. The value of $B_{lim}$ appears as a reasonable choice for $B_{lim}$: only low recruitments have been observed with SSB below this level whereas both high and low recruitments have been seen at higher SSB values. SSB is well above $B_{lim}$ in 2011. In Figure 21a, we can see a very high uncertainty in the recruitment of year 2010. Figure 22 shows the Bayesian Yield per Recruit with respect to $F_{bar}$, in which the estimated values for $F_{0.1}$ (0.13), $F_{max}$ (0.21) and $F_{2010}$ (0.28) are indicated.

## Retrospective pattern

A retrospective analysis of six years was made (Figure 23). Recruitment is over estimated year by year. No patterns are observed for total biomass, SSB and $F_{bar}$.

## Projections

Stochastic projections over a three years period (2012-2014) have been performed. The 2011 data were included in the tables in order to compare the results. Variability of input data was taken from the results of the Bayesian assessment. Input data were as follows:

**Numbers aged 2 to 8+ in 2011:** estimates from the assessment

**Recruitments for 2011-2014:** Recruits per spawner were estimated for each year (Figure 24). As the variability over the years of the assessment is very high, using just the last 3 years was not considered realistic. Hence, in the projections, recruits per spawner were drawn randomly from all years (1988-2010).

**Maturity ogive:** Drawn randomly from the maturity ogives (with their associated uncertainty) of the last three years of the assessment (2008-2010).

**Weight-at-age in stock and weight-at-age in catch:** Drawn randomly from the last 3 years (2008-2010) (Tables 4 and 5).

**PR at age for 2010-2013:** There is only one year of open fishery, so the PR was calculated as the PR of that year (2010). Last year an average of the PRs for 1988-1998 was used, the period in which the fishery had been open before 2010. The two PR are compared in Figure 25, showing differences between the two PRs.

**$F_{bar}$(ages 3-5):** Six options were considered. All Scenarios assumed that the 2011 catch is the TAC (10 000 tons):

**1.** Average of $F_{bar}$ in 2008-2010 (median value at 0.128).
**2.** $F_{0.1}$ (median value at 0.130).
**3.** Average of $F_{bar}$ in 1988-1995 (median value at 0.967), as these years correspond to the period when SSB was above $B_{lim}$.
**4.** $F_{max}$ (median value at 0.210).
**5.** F=0.
**6.** $F_{statusquo}$ (median value at 0.280).

Results for the six options are presented in Tables 10-21 and Figures 26 and 27. They indicate that total biomass and SSB has a very high probability of reaching levels higher than the 1988-2010 estimated level for all options except option 3 ($F_{bar}$ equal to the average of 1988-1995 $F_{bar}$). The increase in SSB is higher then in total biomass. However, the huge increase predicted for SSB does not have a counterpart for the mature abundances, which are projected to remain at levels below these of the late 1980´s or just above. This is largely due to the fact that weight-at-age and maturity-at-age used for the projection period, namely random draws from the last 3 assessment years, are much higher than those assumed to have applied at the end of the 1980's.

Results indicate that fishing at the $F_{bar}$ level currently estimated for 2010 should allow SSB to increase slowly, although abundance will remain at levels below those observed at the beginning of the series. If the fishing mortality were return to the levels seen before 1995, stock recovery would become improbable.

The projected values for the period 2012-2014 are heavily reliant on the relatively abundant six most recent cohorts, namely those recruited in 2005-2010.

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## Acknowledges

Thanks to Fernando González-Costas for his valuable comments. The authors would like to thank too to all the people that make possible this type of works: onboard observers, both in commercial and survey vessels, who obtain the data, and lab people who have processed them.

This study was supported by the European Commission (Program for the Collection of Data in Fisheries Sector), the IEO, the CSIC and the INRB\IPIMAR.

**Table 1.-** Total commercial cod catch in Division 3M. Reported nominal catches since 1960 and estimated total catch since 1988 in tons

| Year | Estimated[1] | Portugal | Russia | Spain | France | Faroes | UK | Poland | Norway | Germany | Cuba | Others | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1960 | | 9 | 11595 | 607 | | | | | 46 | 86 | | 10 | 12353 |
| 1961 | | 2155 | 12379 | 851 | 2626 | | 600 | 336 | | 1394 | | 0 | 20341 |
| 1962 | | 2032 | 11282 | 1234 | | | 93 | 888 | 25 | 4 | | 349 | 15907 |
| 1963 | | 7028 | 8528 | 4005 | 9501 | | 2476 | 1875 | | 0 | | 0 | 33413 |
| 1964 | | 3668 | 26643 | 862 | 3966 | | 2185 | 718 | 660 | 83 | | 12 | 38797 |
| 1965 | | 1480 | 37047 | 1530 | 2039 | | 6104 | 5073 | 11 | 313 | | 458 | 54055 |
| 1966 | | 7336 | 5138 | 4268 | 4603 | | 7259 | 93 | | 259 | | 0 | 28956 |
| 1967 | | 10728 | 5886 | 3012 | 6757 | | 5732 | 4152 | | 756 | | 46 | 37069 |
| 1968 | | 10917 | 3872 | 4045 | 13321 | | 1466 | 71 | | 0 | | 458 | 34150 |
| 1969 | | 7276 | 283 | 2681 | 11831 | | | | | 20 | | 52 | 22143 |
| 1970 | | 9847 | 494 | 1324 | 6239 | | 3 | 53 | | 0 | | 35 | 17995 |
| 1971 | | 7272 | 5536 | 1063 | 9006 | | | 19 | | 1628 | | 25 | 24549 |
| 1972 | | 32052 | 5030 | 5020 | 2693 | 6902 | 4126 | 35 | 261 | 506 | | 187 | 56812 |
| 1973 | | 11129 | 1145 | 620 | 132 | 7754 | 1183 | 481 | 417 | 21 | | 18 | 22900 |
| 1974 | | 10015 | 5998 | 2619 | | 1872 | 3093 | 700 | 383 | 195 | | 63 | 24938 |
| 1975 | | 10430 | 5446 | 2022 | | 3288 | 265 | 677 | 111 | 28 | | 108 | 22375 |
| 1976 | | 10120 | 4831 | 2502 | 229 | 2139 | | 898 | 1188 | 225 | | 134 | 22266 |
| 1977 | | 6652 | 2982 | 1315 | 5827 | 5664 | 1269 | 843 | 867 | 45 | 1002 | 553 | 27019 |
| 1978 | | 10157 | 3779 | 2510 | 5096 | 7922 | 207 | 615 | 1584 | 410 | 562 | 289 | 33131 |
| 1979 | | 9636 | 4743 | 4907 | 1525 | 7484 | | 5 | 1310 | 0 | 24 | 76 | 29710 |
| 1980 | | 3615 | 1056 | 706 | 301 | 3248 | | 33 | 1080 | 355 | 1 | 62 | 10457 |
| 1981 | | 3727 | 927 | 4100 | 79 | 3874 | | | 1154 | 0 | | 12 | 13873 |
| 1982 | | 3316 | 1262 | 4513 | 119 | 3121 | 33 | | 375 | 0 | | 14 | 12753 |
| 1983 | | 2930 | 1264 | 4407 | | 1489 | | | 111 | 3 | | 1 | 10205 |
| 1984 | | 3474 | 910 | 4745 | | 3058 | | | 47 | 454 | 5 | 9 | 12702 |
| 1985 | | 4376 | 1271 | 4914 | | 2266 | | | 405 | 429 | 9 | 5 | 13675 |
| 1986 | | 6350 | 1231 | 4384 | | 2192 | | | | 345 | 3 | 13 | 14518 |
| 1987 | | 2802 | 706 | 3639 | 2300 | 916 | | | | 0 | | 269 | 10632 |
| 1988 | 28899 | 421 | 39 | 141 | | 1100 | | | | 0 | 3 | 14 | 1718 |
| 1989 | 48373 | 170 | 10 | 378 | | | | | | 0 | | 359 | 917 |
| 1990 | 40827 | 551 | 22 | 87 | | 1262 | | | | 0 | | 840 | 2762 |
| 1991 | 16229 | 2838 | 1 | 1416 | | 2472 | 26 | | 897 | 0 | 5 | 1334 | 8989 |
| 1992 | 25089 | 2201 | 1 | 4215 | | 747 | 5 | | | 0 | 6 | 51 | 7226 |
| 1993 | 15958 | 3132 | 0 | 2249 | | 2931 | | | | 0 | | 4 | 8316 |
| 1994 | 29916 | 2590 | 0 | 1952 | | 2249 | | | 1 | 0 | | 93 | 6885 |
| 1995 | 10372 | 1641 | 0 | 564 | | 1016 | | | | 0 | | 0 | 3221 |
| 1996 | 2601 | 1284 | 0 | 176 | | 700 | 129 | | | 16 | | 0 | 2305 |
| 1997 | 2933 | 1433 | 0 | 1 | | | 23 | | | 0 | | 0 | 1457 |
| 1998 | 705 | 456 | 0 | | | | | | | 0 | | 0 | 456 |
| 1999 | 353 | 2 | 0 | | | | | | | 0 | | 0 | 2 |
| 2000 | 55 | 30 | 6 | | | | | | | 0 | | 0 | 36 |
| 2001 | 37 | 56 | 0 | | | | | | | 0 | | 0 | 56 |
| 2002 | 33 | 32 | 1 | | | | | | | 0 | | 0 | 33 |
| 2003 | 16 | 7 | 0 | | | | | | | 0 | | 9 | 16 |
| 2004 | 5 | 18 | 2 | | | | | | | 0 | | 3 | 23 |
| 2005 | 19 | 16 | 0 | | | 7 | | | | 0 | | 3 | 26 |
| 2006 | 339 | 51 | 1 | 16 | | | | | | 0 | | 55 | 123 |
| 2007 | 345 | 58 | 6 | 33 | | | | | | 0 | | 28 | 125 |
| 2008 | 889 | 219 | 74 | 42 | | 0 | | | | 0 | | 66 | 401 |
| 2009 | 1161 | 856 | 87 | 85 | | 22 | | | | 0 | | 122 | 1172 |
| 2010 | 9192 | 1482 | 374 | | | 1183 | 761 | | 519 | 0 | | 85 | 4404 |

[1] Recalculated from NAFO Statistical data base using the NAFO 21A Extraction Tool

**Table 2.-** Catch-at-age (thousands)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ |
|---|---|---|---|---|---|---|---|---|
| 1988 | 1 | 3500 | 25593 | 11161 | 1399 | 414 | 315 | 162 |
| 1989 | 0 | 52 | 15399 | 23233 | 9373 | 943 | 220 | 205 |
| 1990 | 7 | 254 | 2180 | 15740 | 10824 | 2286 | 378 | 117 |
| 1991 | 1 | 561 | 5196 | 1960 | 3151 | 1688 | 368 | 76 |
| 1992 | 0 | 15517 | 10180 | 4865 | 3399 | 2483 | 1106 | 472 |
| 1993 | 0 | 2657 | 14530 | 3547 | 931 | 284 | 426 | 213 |
| 1994 | 0 | 1219 | 25400 | 8273 | 386 | 185 | 14 | 182 |
| 1995 | 0 | 0 | 264 | 6553 | 2750 | 651 | 135 | 232 |
| 1996 | 0 | 81 | 714 | 311 | 1072 | 88 | 0 | 0 |
| 1997 | 0 | 0 | 810 | 762 | 143 | 286 | 48 | 0 |
| 1998 | 0 | 0 | 8 | 170 | 286 | 30 | 19 | 2 |
| 1999 | 0 | 0 | 15 | 15 | 96 | 60 | 3 | 1 |
| 2000 | 0 | 10 | 54 | 1 | 1 | 4 | 1 | 0 |
| 2001 | 0 | 9 | 0 | 4 | 2 | 0 | 2 | 2 |
| 2002 | | | | | | | | |
| 2003 | | | | | | | | |
| 2004 | | | | | | | | |
| 2005 | | | | | | | | |
| 2006 | 0 | 22 | 19 | 81 | 2 | 10 | 2 | 0 |
| 2007 | 0 | 2 | 30 | 1 | 27 | 1 | 14 | 5 |
| 2008 | 1 | 89 | 136 | 133 | 3 | 40 | 1 | 3 |
| 2009 | 0 | 23 | 51 | 210 | 108 | 0 | 32 | 7 |
| 2010 | 34 | 452 | 1145 | 1498 | 808 | 388 | 4 | 103 |

**Table 3.-** EU bottom trawl survey abundance at age (thousands)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1988 | 4850 | 78920 | 49050 | 13370 | 1450 | 210 | 220 | 60 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1989 | 22100 | 12100 | 106400 | 63400 | 23800 | 1600 | 200 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1990 | 2660 | 14020 | 5920 | 19970 | 18420 | 5090 | 390 | 170 | 90 | 30 | 0 | 0 | 0 | 0 |
| 1991 | 146100 | 29400 | 20600 | 2500 | 7800 | 2100 | 300 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1992 | 75480 | 44280 | 6290 | 2540 | 410 | 1500 | 270 | 10 | 0 | 0 | 10 | 0 | 0 | 0 |
| 1993 | 4600 | 156100 | 35400 | 1300 | 1500 | 200 | 600 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1994 | 3340 | 4550 | 31580 | 5760 | 150 | 70 | 10 | 120 | 0 | 10 | 0 | 0 | 0 | 0 |
| 1995 | 1640 | 13670 | 1540 | 4490 | 1070 | 40 | 30 | 0 | 20 | 10 | 0 | 0 | 0 | 0 |
| 1996 | 41 | 3580 | 7649 | 1020 | 2766 | 221 | 9 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1997 | 42 | 171 | 3931 | 5430 | 442 | 1078 | 24 | 0 | 0 | 0 | 0 | 6 | 0 | 0 |
| 1998 | 27 | 94 | 106 | 1408 | 1763 | 87 | 165 | 0 | 6 | 0 | 0 | 0 | 0 | 0 |
| 1999 | 7 | 96 | 128 | 129 | 792 | 491 | 21 | 7 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 186 | 16 | 343 | 207 | 100 | 467 | 180 | 11 | 17 | 0 | 0 | 5 | 0 | 5 |
| 2001 | 487 | 2048 | 15 | 125 | 81 | 15 | 146 | 101 | 6 | 6 | 6 | 0 | 0 | 0 |
| 2002 | 0 | 1340 | 609 | 24 | 68 | 36 | 28 | 96 | 33 | 0 | 6 | 0 | 0 | 0 |
| 2003 | 665 | 53 | 610 | 131 | 22 | 47 | 7 | 8 | 37 | 25 | 0 | 0 | 0 | 0 |
| 2004 | 0 | 3379 | 25 | 602 | 168 | 5 | 10 | 3 | 5 | 16 | 0 | 0 | 0 | 0 |
| 2005 | 8069 | 16 | 1118 | 78 | 708 | 136 | | 17 | 8 | 8 | 0 | 0 | 0 | 0 |
| 2006 | 19710 | 3883 | 62 | 1481 | 86 | 592 | 115 | 7 | 0 | 7 | 14 | 0 | 7 | 0 |
| 2007 | 3910 | 11620 | 5020 | 21 | 1138 | 58 | 425 | 74 | 13 | 20 | 0 | 0 | 0 | 0 |
| 2008 | 6090 | 16670 | 12440 | 4530 | 70 | 940 | 60 | 230 | 80 | 0 | 10 | 0 | 0 | 0 |
| 2009 | 5139 | 7479 | 16150 | 14310 | 4154 | 26 | 1091 | 0 | 335 | 0 | 0 | 14 | 0 | 0 |
| 2010 | 66370 | 27689 | 8654 | 7633 | 4911 | 1780 | 8 | 442 | 46 | 251 | 26 | 0 | 0 | 0 |

**Table 4.-** Weight-at-age (kg) in catch

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ |
|---|---|---|---|---|---|---|---|---|
| 1988 | 0.058 | 0.198 | 0.442 | 0.821 | 2.190 | 3.386 | 5.274 | 7.969 |
| 1989 | | 0.209 | 0.576 | 0.918 | 1.434 | 2.293 | 4.721 | 7.648 |
| 1990 | 0.080 | 0.153 | 0.500 | 0.890 | 1.606 | 2.518 | 3.554 | 7.166 |
| 1991 | 0.118 | 0.229 | 0.496 | 0.785 | 1.738 | 2.622 | 3.474 | 6.818 |
| 1992 | | 0.298 | 0.414 | 0.592 | 1.093 | 1.704 | 2.619 | 3.865 |
| 1993 | | 0.210 | 0.509 | 0.894 | 1.829 | 2.233 | 3.367 | 4.841 |
| 1994 | | 0.289 | 0.497 | 0.792 | 1.916 | 2.719 | 2.158 | 4.239 |
| 1995 | | | 0.415 | 0.790 | 1.447 | 2.266 | 3.960 | 5.500 |
| 1996 | | 0.286 | 0.789 | 1.051 | 1.543 | 2.429 | | |
| 1997 | | | 0.402 | 0.640 | 0.869 | 1.197 | 1.339 | |
| 1998 | | | 0.719 | 1.024 | 1.468 | 1.800 | 2.252 | 3.862 |
| 1999 | | | 0.92 | 1.298 | 1.848 | 2.436 | 3.513 | 4.893 |
| 2000 | | 0.583 | 0.672 | 1.749 | 2.054 | 2.836 | 3.618 | |
| 2001 | | 0.481 | | 1.696 | 2.560 | | 3.905 | 5.217 |
| 2002 | | 0.588 | 1.323 | 1.388 | 2.572 | 3.770 | 5.158 | 5.603 |
| 2003 | | 0.462 | 1.063 | 1.455 | 2.978 | 3.696 | 5.859 | 6.120 |
| 2004 | | 0.839 | 1.677 | 2.009 | 3.353 | 5.576 | 6.241 | 8.273 |
| 2005 | | 0.895 | 1.618 | 2.368 | 3.259 | 4.767 | 6.177 | 6.553 |
| 2006 | | 1.081 | 1.462 | 2.283 | 3.966 | 5.035 | 6.332 | |
| 2007 | | 0.974 | 1.858 | 3.388 | 4.062 | 6.128 | 6.809 | 9.440 |
| 2008 | 0.088 | 0.448 | 1.364 | 3.037 | 3.498 | 5.248 | 6.643 | 8.251 |
| 2009 | 0.172 | 0.507 | 1.026 | 2.087 | 3.727 | | 5.900 | 9.534 |
| 2010 | 0.162 | 0.700 | 1.279 | 1.829 | 2.764 | 4.372 | 4.199 | 8.575 |

**Table 5.-** Weight-at-age (kg) in stock

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ |
|---|---|---|---|---|---|---|---|---|
| 1988 | 0.03 | 0.10 | 0.31 | 0.68 | 1.97 | 3.59 | 5.77 | 6.93 |
| 1989 | 0.04 | 0.24 | 0.54 | 1.04 | 1.60 | 2.51 | 4.27 | 6.93 |
| 1990 | 0.04 | 0.17 | 0.34 | 0.85 | 1.50 | 2.43 | 4.08 | 5.64 |
| 1991 | 0.05 | 0.17 | 0.50 | 0.86 | 1.61 | 2.61 | 4.26 | 7.69 |
| 1992 | 0.05 | 0.25 | 0.49 | 1.38 | 1.70 | 2.63 | 3.13 | 6.69 |
| 1993 | 0.04 | 0.22 | 0.66 | 1.21 | 2.27 | 2.37 | 3.45 | 5.89 |
| 1994 | 0.06 | 0.21 | 0.59 | 1.32 | 2.26 | 4.03 | 4.03 | 6.72 |
| 1995 | 0.05 | 0.24 | 0.47 | 0.96 | 1.85 | 3.16 | 5.56 | 8.48 |
| 1996 | 0.04 | 0.25 | 0.53 | 0.80 | 1.32 | 2.27 | 4.00 | 5.03 |
| 1997 | 0.08 | 0.32 | 0.64 | 1.00 | 1.31 | 2.10 | 2.00 | 9.57 |
| 1998 | 0.07 | 0.36 | 0.75 | 1.19 | 1.66 | 1.99 | 3.10 | 7.40 |
| 1999 | 0.10 | 0.37 | 0.92 | 1.30 | 1.85 | 2.44 | 3.51 | 4.89 |
| 2000 | 0.10 | 0.58 | 0.96 | 1.61 | 1.91 | 2.83 | 3.47 | 5.28 |
| 2001 | 0.08 | 0.48 | 1.25 | 1.70 | 2.56 | 3.42 | 3.91 | 5.22 |
| 2002 | 0.00 | 0.42 | 1.12 | 1.43 | 2.47 | 3.59 | 4.86 | 5.31 |
| 2003 | 0.05 | 0.33 | 0.90 | 1.50 | 2.86 | 3.52 | 5.52 | 5.80 |
| 2004 | 0.07 | 0.6 | 1.42 | 2.07 | 3.22 | 5.31 | 5.88 | 7.84 |
| 2005 | 0.02 | 0.64 | 1.37 | 2.44 | 3.13 | 4.54 | | 6.21 |
| 2006 | 0.09 | 0.7 | 1.06 | 2.49 | 3.57 | 4.69 | 5.76 | 9.55 |
| 2007 | 0.05 | 0.59 | 1.60 | 3.40 | 4.01 | 5.69 | 6.27 | 8.76 |
| 2008 | 0.07 | 0.38 | 1.34 | 2.69 | 3.19 | 5.02 | 6.32 | 7.94 |
| 2009 | 0.08 | 0.41 | 0.98 | 2.07 | 3.88 | 6.96 | 6.58 | 9.46 |
| 2010 | 0.06 | 0.38 | 1.09 | 1.68 | 2.96 | 5.38 | 7.62 | 9.14 |

**Table 6.-** Maturity at age (median values of ogives)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1988 | 0.054 | 0.099 | 0.175 | 0.291 | 0.441 | 0.603 | 0.745 | 0.879 |
| 1989 | 0.054 | 0.099 | 0.175 | 0.291 | 0.441 | 0.603 | 0.745 | 0.879 |
| 1990 | 0.054 | 0.099 | 0.175 | 0.291 | 0.441 | 0.603 | 0.745 | 0.879 |
| 1991 | 0.016 | 0.044 | 0.108 | 0.247 | 0.462 | 0.698 | 0.867 | 0.962 |
| 1992 | 0.002 | 0.011 | 0.048 | 0.184 | 0.503 | 0.819 | 0.953 | 0.993 |
| 1993 | 0.001 | 0.007 | 0.049 | 0.282 | 0.751 | 0.959 | 0.994 | 1.000 |
| 1994 | 0.000 | 0.001 | 0.050 | 0.657 | 0.986 | 1.000 | 1.000 | 1.000 |
| 1995 | 0.000 | 0.000 | 0.006 | 0.803 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1996 | 0.000 | 0.000 | 0.029 | 0.666 | 0.993 | 1.000 | 1.000 | 1.000 |
| 1997 | 0.000 | 0.008 | 0.111 | 0.670 | 0.971 | 0.998 | 1.000 | 1.000 |
| 1998 | 0.000 | 0.002 | 0.096 | 0.874 | 0.998 | 1.000 | 1.000 | 1.000 |
| 1999 | 0.000 | 0.001 | 0.131 | 0.902 | 0.999 | 1.000 | 1.000 | 1.000 |
| 2000 | 0.000 | 0.001 | 0.163 | 0.966 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2001 | 0.000 | 0.001 | 0.315 | 0.998 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2002 | 0.000 | 0.010 | 0.636 | 0.997 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2003 | 0.001 | 0.024 | 0.513 | 0.978 | 0.999 | 1.000 | 1.000 | 1.000 |
| 2004 | 0.000 | 0.000 | 0.100 | 0.967 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2005 | 0.041 | 0.171 | 0.502 | 0.830 | 0.959 | 0.991 | 0.998 | 1.000 |
| 2006 | 0.000 | 0.014 | 0.365 | 0.959 | 0.999 | 1.000 | 1.000 | 1.000 |
| 2007 | 0.000 | 0.014 | 0.365 | 0.959 | 0.999 | 1.000 | 1.000 | 1.000 |
| 2008 | 0.000 | 0.012 | 0.231 | 0.882 | 0.995 | 1.000 | 1.000 | 1.000 |
| 2009 | 0.000 | 0.010 | 0.181 | 0.830 | 0.991 | 1.000 | 1.000 | 1.000 |
| 2010 | 0.000 | 0.009 | 0.167 | 0.812 | 0.989 | 1.000 | 1.000 | 1.000 |

**Table 7.-** Posterior results: total biomass, SSB, recruitment (tons) and $F_{bar}$.

| | **B quantiles** | | | **SSB quantiles** | | | **R quantiles** | | | **$F_{bar}$ quantiles** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **50%** | **5%** | **95%** | **50%** | **5%** | **95%** | **50%** | **5%** | **95%** | **50%** | **5%** | **95%** |
| **1988** | 64272 | 59672 | 70682 | 19171 | 15344 | 23905 | 13985 | 11689 | 17801 | 0.516 | 0.472 | 0.550 |
| **1989** | 104105 | 98317 | 112194 | 33479 | 27446 | 40865 | 18790 | 16120 | 23110 | 0.872 | 0.813 | 0.915 |
| **1990** | 64070 | 60573 | 68922 | 25460 | 21751 | 29548 | 23785 | 20680 | 28700 | 0.910 | 0.853 | 0.954 |
| **1991** | 44017 | 40920 | 48685 | 17828 | 15020 | 21552 | 60410 | 53460 | 71300 | 0.500 | 0.467 | 0.527 |
| **1992** | 57678 | 54759 | 62008 | 21001 | 18460 | 23939 | 54720 | 47950 | 65350 | 1.555 | 1.476 | 1.614 |
| **1993** | 45718 | 42792 | 49862 | 10647 | 8966 | 13419 | 2978 | 2615 | 3566 | 1.038 | 0.968 | 1.093 |
| **1994** | 49645 | 46327 | 55310 | 21735 | 18782 | 27069 | 4219 | 3204 | 6167 | 0.958 | 0.912 | 0.994 |
| **1995** | 22578 | 21333 | 24480 | 19301 | 18124 | 21000 | 2166 | 1788 | 2827 | 1.397 | 1.254 | 1.504 |
| **1996** | 5892 | 5197 | 6935 | 3560 | 3137 | 4267 | 135 | 89 | 215 | 0.643 | 0.528 | 0.742 |
| **1997** | 5082 | 4259 | 6383 | 3459 | 2817 | 4506 | 130 | 85 | 209 | 0.709 | 0.565 | 0.856 |
| **1998** | 3893 | 2817 | 5633 | 3673 | 2623 | 5394 | 196 | 141 | 291 | 0.284 | 0.205 | 0.385 |
| **1999** | 2812 | 1895 | 4400 | 2669 | 1760 | 4237 | 33 | 24 | 49 | 0.270 | 0.200 | 0.361 |
| **2000** | 2631 | 1633 | 4452 | 2477 | 1478 | 4274 | 332 | 207 | 528 | 0.184 | 0.126 | 0.258 |
| **2001** | 2136 | 1465 | 3093 | 1930 | 1272 | 2859 | 586 | 370 | 943 | 0.033 | 0.023 | 0.047 |
| **2002** | 2499 | 1827 | 3457 | 2183 | 1531 | 3116 | 69 | 44 | 111 | 0.014 | 0.007 | 0.029 |
| **2003** | 2798 | 2137 | 3707 | 2511 | 1877 | 3404 | 1252 | 817 | 1901 | 0.010 | 0.006 | 0.017 |
| **2004** | 4490 | 3613 | 5645 | 3727 | 2921 | 4831 | 79 | 58 | 115 | 0.003 | 0.002 | 0.005 |
| **2005** | 4883 | 4040 | 5944 | 4047 | 3323 | 4984 | 3955 | 2491 | 6512 | 0.006 | 0.004 | 0.010 |
| **2006** | 7680 | 6139 | 9764 | 4333 | 3470 | 5438 | 8808 | 5318 | 14951 | 0.209 | 0.159 | 0.267 |
| **2007** | 14618 | 11334 | 19210 | 6600 | 5042 | 8528 | 9226 | 5668 | 15891 | 0.028 | 0.021 | 0.037 |
| **2008** | 22688 | 17301 | 30081 | 11359 | 8658 | 15186 | 7550 | 4455 | 13100 | 0.069 | 0.052 | 0.092 |
| **2009** | 34003 | 26227 | 43828 | 22233 | 16698 | 29759 | 12950 | 6235 | 27790 | 0.038 | 0.027 | 0.052 |
| **2010** | 50204 | 39520 | 64172 | 36278 | 27730 | 47189 | 26510 | 9706 | 73585 | 0.275 | 0.196 | 0.397 |
| **2011** | | | | 50291 | 35132 | 71833 | | | | | | |

**Table 8.-** F at age (posterior median)

| | F at age | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Year** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8+** |
| **1988** | 0.000 | 0.068 | 0.439 | 0.557 | 0.555 | 0.746 | 1.258 | 1.258 |
| **1989** | 0.000 | 0.005 | 0.443 | 0.870 | 1.308 | 0.878 | 1.160 | 1.160 |
| **1990** | 0.000 | 0.017 | 0.258 | 1.086 | 1.388 | 1.463 | 1.069 | 1.069 |
| **1991** | 0.000 | 0.030 | 0.525 | 0.368 | 0.611 | 0.790 | 0.967 | 0.967 |
| **1992** | 0.000 | 0.388 | 1.024 | 1.391 | 2.257 | 1.491 | 2.525 | 2.525 |
| **1993** | 0.000 | 0.063 | 0.724 | 1.279 | 1.117 | 1.794 | 1.163 | 1.163 |
| **1994** | 0.000 | 0.720 | 1.266 | 1.212 | 0.398 | 0.648 | 0.341 | 0.341 |
| **1995** | 0.000 | 0.000 | 0.309 | 1.448 | 2.452 | 3.213 | 1.486 | 1.486 |
| **1996** | 0.000 | 0.048 | 0.284 | 0.686 | 0.966 | 0.503 | 0.000 | 0.000 |
| **1997** | 0.000 | 0.000 | 0.845 | 0.525 | 0.750 | 0.703 | 0.539 | 0.539 |
| **1998** | 0.000 | 0.000 | 0.090 | 0.392 | 0.358 | 0.319 | 0.082 | 0.082 |
| **1999** | 0.000 | 0.000 | 0.184 | 0.232 | 0.379 | 0.111 | 0.045 | 0.045 |
| **2000** | 0.000 | 0.478 | 0.513 | 0.016 | 0.020 | 0.023 | 0.002 | 0.002 |
| **2001** | 0.000 | 0.035 | 0.000 | 0.059 | 0.038 | 0.000 | 0.013 | 0.013 |
| **2002** | 0.000 | 0.006 | 0.014 | 0.010 | 0.011 | 0.005 | 0.013 | 0.013 |
| **2003** | 0.000 | 0.005 | 0.009 | 0.009 | 0.010 | 0.005 | 0.004 | 0.004 |
| **2004** | 0.000 | 0.001 | 0.005 | 0.002 | 0.002 | 0.004 | 0.001 | 0.001 |
| **2005** | 0.000 | 0.005 | 0.004 | 0.009 | 0.005 | 0.004 | 0.003 | 0.003 |
| **2006** | 0.000 | 0.007 | 0.441 | 0.118 | 0.064 | 0.043 | 0.015 | 0.015 |
| **2007** | 0.000 | 0.000 | 0.011 | 0.022 | 0.050 | 0.046 | 0.071 | 0.071 |
| **2008** | 0.000 | 0.012 | 0.023 | 0.060 | 0.122 | 0.092 | 0.058 | 0.058 |
| **2009** | 0.000 | 0.004 | 0.008 | 0.042 | 0.060 | 0.000 | 0.092 | 0.092 |
| **2010** | 0.001 | 0.045 | 0.250 | 0.330 | 0.214 | 0.301 | 0.266 | 0.266 |

**Table 9.-** N at age (posterior median), with the total number and number of matures by year.

| | N at age | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8+** | **Total** | **Matures** |
| **1988** | 13985 | 57580 | 77620 | 28150 | 3545 | 851 | 474 | 240 | 182445 | 31190 |
| **1989** | 18790 | 12040 | 46330 | 43100 | 13875 | 1742 | 346 | 317 | 136540 | 30781 |
| **1990** | 23785 | 16180 | 10320 | 25625 | 15550 | 3217 | 621 | 190 | 95488 | 21776 |
| **1991** | 60410 | 20480 | 13700 | 6866 | 7441 | 3340 | 639 | 130 | 113006 | 11936 |
| **1992** | 54720 | 52020 | 17120 | 6981 | 4095 | 3462 | 1299 | 538 | 140235 | 9617 |
| **1993** | 2978 | 47130 | 30400 | 5296 | 1494 | 368 | 667 | 329 | 88662 | 5858 |
| **1994** | 4219 | 2561 | 38120 | 12700 | 1269 | 419 | 52 | 678 | 60018 | 12812 |
| **1995** | 2166 | 3629 | 1072 | 9249 | 3251 | 733 | 188 | 317 | 20605 | 11970 |
| **1996** | 135 | 1862 | 3121 | 675 | 1869 | 240 | 25 | 1 | 7928 | 2699 |
| **1997** | 130 | 116 | 1529 | 2018 | 292 | 610 | 124 | 1 | 4820 | 2605 |
| **1998** | 196 | 112 | 100 | 565 | 1026 | 119 | 260 | 27 | 2405 | 1996 |
| **1999** | 33 | 168 | 96 | 78 | 328 | 616 | 74 | 25 | 1418 | 1160 |
| **2000** | 332 | 28 | 145 | 69 | 53 | 193 | 474 | 1 | 1295 | 845 |
| **2001** | 586 | 285 | 15 | 75 | 58 | 45 | 162 | 162 | 1388 | 514 |
| **2002** | 69 | 504 | 237 | 13 | 61 | 48 | 39 | 275 | 1246 | 602 |
| **2003** | 1252 | 59 | 432 | 200 | 11 | 51 | 41 | 267 | 2313 | 807 |
| **2004** | 79 | 1076 | 51 | 368 | 170 | 9 | 44 | 265 | 2062 | 864 |
| **2005** | 3955 | 68 | 926 | 43 | 316 | 146 | 8 | 267 | 5729 | 1433 |
| **2006** | 8808 | 3406 | 58 | 792 | 37 | 270 | 125 | 23 | 13519 | 1303 |
| **2007** | 9226 | 7583 | 2909 | 32 | 603 | 30 | 221 | 74 | 20678 | 2157 |
| **2008** | 7550 | 7922 | 6536 | 2466 | 27 | 493 | 24 | 66 | 25084 | 4464 |
| **2009** | 12950 | 6476 | 6726 | 5486 | 1990 | 20 | 388 | 88 | 34124 | 8461 |
| **2010** | 26510 | 11130 | 5560 | 5741 | 4516 | 1612 | 18 | 473 | 55560 | 12672 |
| **2011** | | 22697 | 9132 | 3720 | 3551 | 3140 | 1025 | 324 | 43589 | 13824 |

**Table 10.-** N-at-age in prediction years (medians) with $F_{bar}=F_{bar}$(mean 2008-2010)=0.128 including total number and number of matures.

| Year/Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ | Total | Matures |
|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | 8913 | 22697 | 9132 | 3720 | 3551 | 3140 | 1025 | 324 | 52502 | 13912 |
| 2012 | 9718 | 7632 | 18701 | 6445 | 2476 | 2570 | 2100 | 949 | 50591 | 18480 |
| 2013 | 12718 | 8364 | 6411 | 14284 | 4697 | 1902 | 1895 | 2310 | 52581 | 27879 |
| 2014 | 19481 | 10901 | 7003 | 4862 | 10406 | 3616 | 1401 | 3253 | 60923 | 32999 |

**Table 11.-** Projections results with $F_{bar}=F_{bar}$(mean 2008-2010)=0.128.

| | **Total Biomass quantiles** | | | **SSB quantiles** | | | **$P(SSB<B_{lim})$** | **Yield quantiles** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 5% | 50% | 95% | 5% | 50% | 95% | | 5% | 50% | 95% |
| 2011 | 52407 | 73656 | 102909 | 35487 | 50433 | 71249 | 0.0000 | 5854 | 9726 | 16046 |
| 2012 | 64930 | 96560 | 148302 | 46501 | 65390 | 91634 | 0.0000 | 5115 | 9238 | 16902 |
| 2013 | 76780 | 127015 | 219135 | 63934 | 95531 | 150208 | 0.0000 | 6644 | 13137 | 26994 |
| 2014 | 88274 | 164001 | 309443 | 73481 | 126165 | 229654 | 0.0000 | 6935 | 15579 | 35000 |

**Table 12.-** N-at-age in prediction years (medians) with $F_{bar}=F_{0.1}$=0.13 including total number and number of matures.

| Year/Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ | Total | Matures |
|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | 8495 | 22697 | 9132 | 3720 | 3551 | 3140 | 1025 | 324 | 52084 | 13873 |
| 2012 | 9598 | 7369 | 18732 | 6415 | 2459 | 2566 | 2104 | 943 | 50186 | 18563 |
| 2013 | 13412 | 8267 | 6184 | 14163 | 4705 | 1894 | 1879 | 2322 | 52826 | 27412 |
| 2014 | 19942 | 11588 | 6946 | 4624 | 10282 | 3632 | 1403 | 3247 | 61664 | 32414 |

**Table 13.-** Projections results with $F_{bar}=F_{0.1}$=0.13.

| | **Total Biomass quantiles** | | | **SSB quantiles** | | | **$P(SSB<B_{lim})$** | **Yield quantiles** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 5% | 50% | 95% | 5% | 50% | 95% | | 5% | 50% | 95% |
| 2011 | 52295 | 73217 | 102422 | 35207 | 50337 | 71531 | 0.0000 | 5796 | 9651 | 15961 |
| 2012 | 65139 | 96289 | 149544 | 46314 | 65654 | 92007 | 0.0000 | 4809 | 9265 | 17924 |
| 2013 | 77306 | 125412 | 218815 | 63949 | 95245 | 151422 | 0.0000 | 6029 | 13056 | 27766 |
| 2014 | 87812 | 161853 | 298153 | 73254 | 123460 | 228973 | 0.0000 | 6388 | 15249 | 36664 |

**Table 14.-** N-at-age in prediction years (medians) with $F_{bar}=F_{bar}$(mean 1988-1995)=0.967 including total number and number of matures.

| Year/Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ | Total | Matures |
|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | 8622 | 22697 | 9132 | 3720 | 3551 | 3140 | 1025 | 324 | 52211 | 13838 |
| 2012 | 9840 | 7450 | 18750 | 6417 | 2456 | 2572 | 2104 | 948 | 50537 | 18561 |
| 2013 | 13212 | 8449 | 5418 | 6553 | 1681 | 960 | 739 | 1017 | 38029 | 13468 |
| 2014 | 9345 | 11380 | 6080 | 1885 | 1706 | 661 | 278 | 585 | 31920 | 10060 |

**Table 15.-** Projections results with $F_{bar}=F_{bar}$(mean 1988-1995)=0.967.

| | **Total Biomass quantiles** | | | **SSB quantiles** | | | **$P(SSB<B_{lim})$** | **Yield quantiles** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 5% | 50% | 95% | 5% | 50% | 95% | | 5% | 50% | 95% |
| 2011 | 52409 | 73420 | 102984 | 35387 | 50598 | 71865 | 0.0000 | 5805 | 9652 | 15539 |
| 2012 | 64849 | 96398 | 148878 | 46575 | 65230 | 91072 | 0.0000 | 29320 | 47053 | 79249 |
| 2013 | 35989 | 68109 | 136462 | 27300 | 43662 | 71484 | 0.0000 | 16452 | 33265 | 73596 |
| 2014 | 20967 | 58160 | 139639 | 14179 | 29488 | 66578 | 0.0452 | 8959 | 26540 | 74026 |

**Table 16.-** N-at-age in prediction years (medians) with $F_{max}$=0.21 including total number and number of matures.

| Year/Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ | Total | Matures |
|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | 9037 | 22697 | 9132 | 3720 | 3551 | 3140 | 1025 | 324 | 52626 | 13896 |
| 2012 | 9946 | 7727 | 18742 | 6429 | 2473 | 2575 | 2101 | 944 | 50937 | 18490 |
| 2013 | 13196 | 8536 | 6367 | 13038 | 4221 | 1775 | 1713 | 2122 | 50968 | 25669 |
| 2014 | 19028 | 11401 | 7086 | 4431 | 8575 | 3055 | 1186 | 2699 | 57461 | 28722 |

**Table 17.-** Projections results with $F_{bar}$=$F_{max}$=0.21.

| | **Total Biomass quantiles** | | | **SSB quantiles** | | | **P(SSB<$B_{lim}$)** | **Yield quantiles** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 5% | 50% | 95% | 5% | 50% | 95% | | 5% | 50% | 95% |
| 2011 | 52245 | 73236 | 102759 | 35232 | 50487 | 71767 | 0.0000 | 5908 | 9754 | 15813 |
| 2012 | 65395 | 96949 | 148571 | 46559 | 65429 | 91648 | 0.0000 | 7608 | 14728 | 28224 |
| 2013 | 71000 | 118180 | 210371 | 57748 | 88166 | 138854 | 0.0000 | 9098 | 19104 | 41108 |
| 2014 | 74024 | 143509 | 277413 | 60717 | 107377 | 200648 | 0.0000 | 8544 | 21304 | 51887 |

**Table 18.-** N-at-age in prediction years (medians) with $F_{bar}$=0 including total number and number of matures.

| Year/Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ | Total | Matures |
|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | 9393 | 22697 | 9132 | 3720 | 3551 | 3140 | 1025 | 324 | 52982 | 13886 |
| 2012 | 10333 | 7974 | 18754 | 6422 | 2462 | 2570 | 2101 | 939 | 51555 | 18584 |
| 2013 | 13656 | 8879 | 6855 | 16107 | 5506 | 2119 | 2204 | 2653 | 57979 | 31284 |
| 2014 | 22453 | 11807 | 7643 | 5930 | 13815 | 4729 | 1822 | 4288 | 72487 | 41294 |

**Table 19.-** Projections results with $F_{bar}$= 0.

| | **Total Biomass quantiles** | | | **SSB quantiles** | | | **P(SSB<$B_{lim}$)** | **Yield quantiles** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 5% | 50% | 95% | 5% | 50% | 95% | | 5% | 50% | 95% |
| 2011 | 52443 | 73210 | 102536 | 35247 | 50523 | 71519 | 0.0000 | 5960 | 9787 | 15744 |
| 2012 | 65526 | 97227 | 148814 | 46608 | 65420 | 91988 | 0.0000 | 0 | 0 | 0 |
| 2013 | 88196 | 141681 | 243396 | 73240 | 108592 | 170287 | 0.0000 | 0 | 0 | 0 |
| 2014 | 114783 | 201914 | 373663 | 96374 | 161204 | 292897 | 0.0000 | 0 | 0 | 0 |

**Table 20.-** N-at-age in prediction years (medians) with $F_{bar}$=$F_{statusquo}$=0.28 including total number and number of matures.

| Year/Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8+ | Total | Matures |
|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | 9016 | 22697 | 9132 | 3720 | 3551 | 3140 | 1025 | 324 | 52605 | 13878 |
| 2012 | 9632 | 7678 | 18754 | 6471 | 2466 | 2569 | 2110 | 944 | 50624 | 18521 |
| 2013 | 13326 | 8154 | 6307 | 12311 | 3911 | 1682 | 1591 | 1993 | 49275 | 24242 |
| 2014 | 16586 | 11395 | 6655 | 4189 | 7453 | 2665 | 1042 | 2362 | 52347 | 25852 |

**Table 21.-** Projections results with $F_{bar}$= $F_{statusquo}$=0.28.

| | **Total Biomass quantiles** | | | **SSB quantiles** | | | **P(SSB<$B_{lim}$)** | **Yield quantiles** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 5% | 50% | 95% | 5% | 50% | 95% | | 5% | 50% | 95% |
| 2011 | 52485 | 73302 | 102483 | 35342 | 50380 | 71937 | 0.0000 | 5879 | 9687 | 16104 |
| 2012 | 65349 | 97325 | 148155 | 46408 | 65464 | 91009 | 0.0000 | 11221 | 18971 | 32165 |
| 2013 | 67067 | 112039 | 200162 | 54681 | 82354 | 130366 | 0.0000 | 12390 | 23568 | 47545 |
| 2014 | 67777 | 129300 | 248623 | 54409 | 94154 | 179882 | 0.0000 | 11194 | 24735 | 56994 |

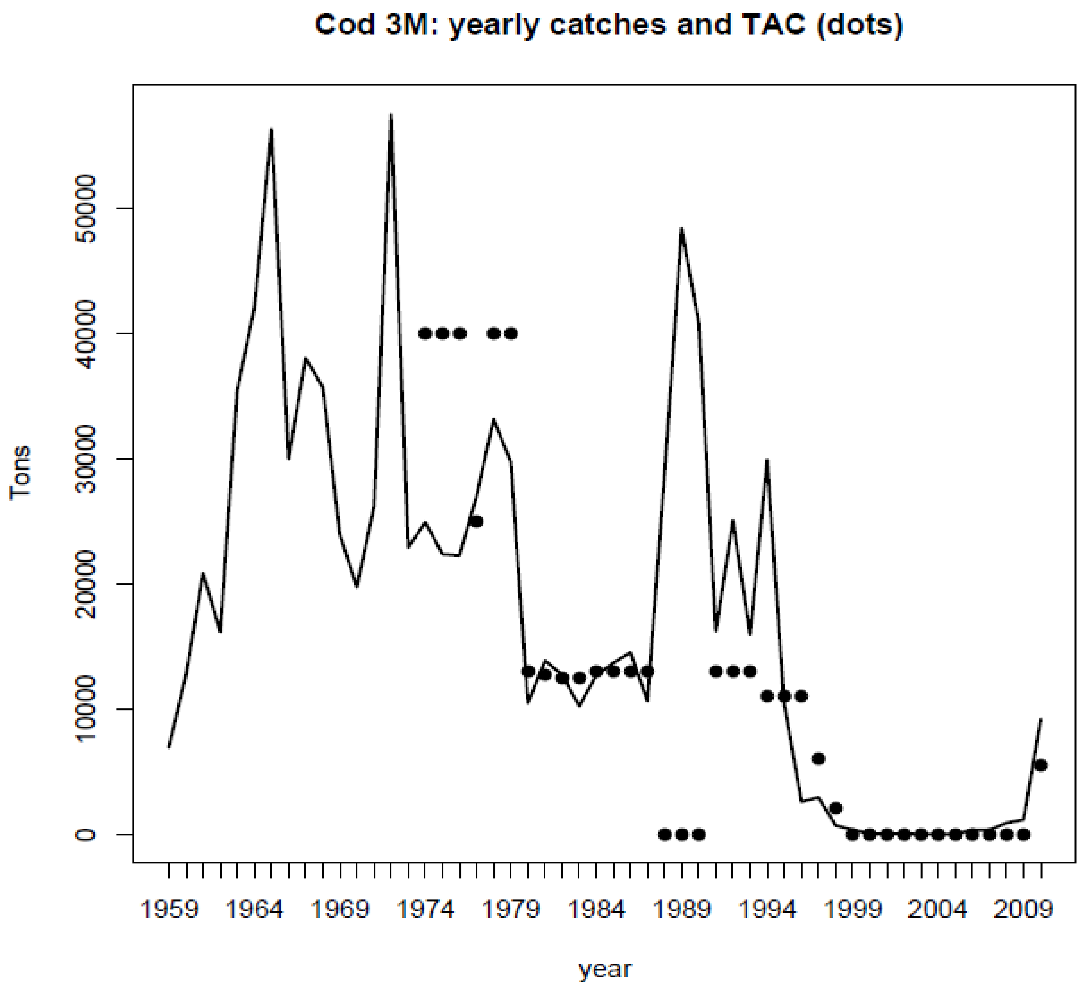


**Figure 1.-** Catch and TAC of the 3M cod for the period 1959-2010

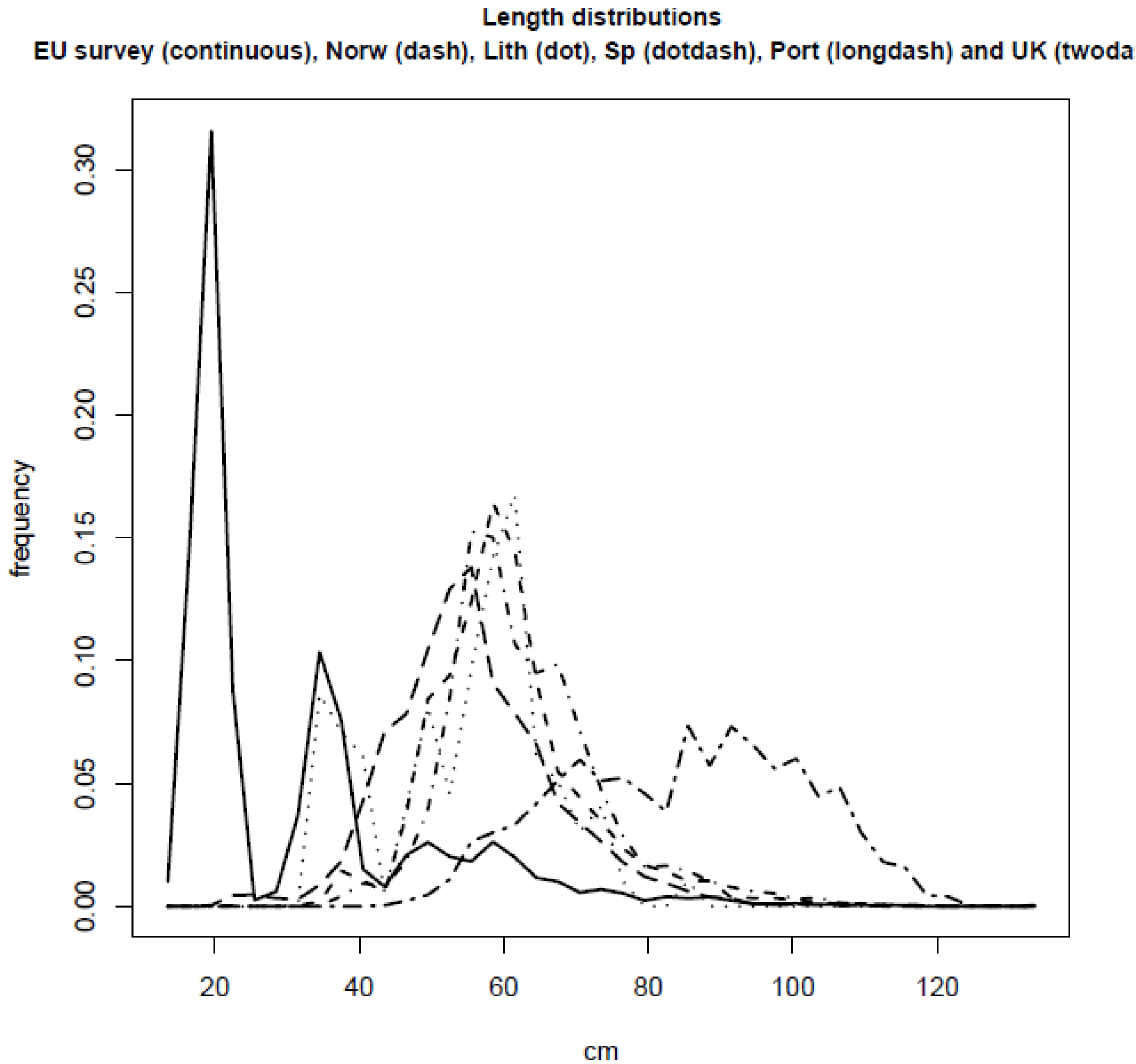


**Figure 2.-** Length frequencies in 2010. Nw: Norway; Lt: Lithuania; Sp: Spain; Pt: Portugal; UK: United Kingdom

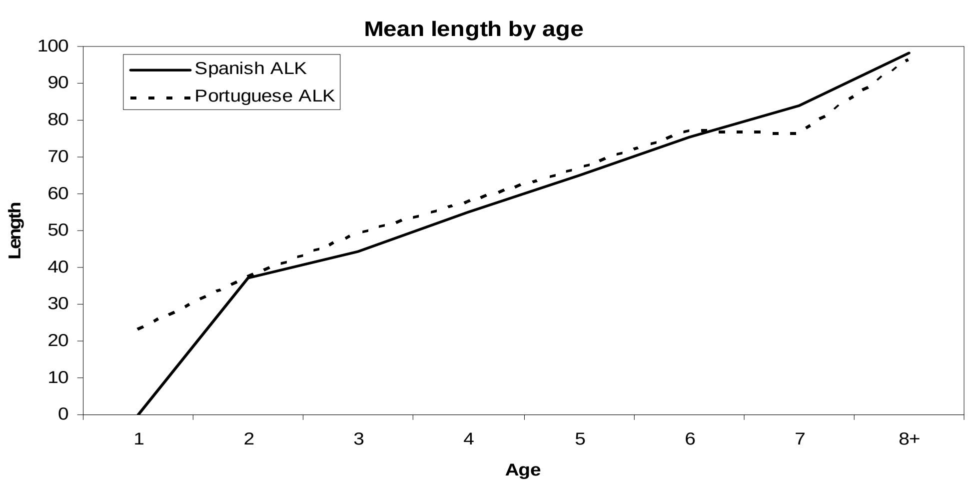


**Figure 3.-** Mean length at age for the two different ALKs

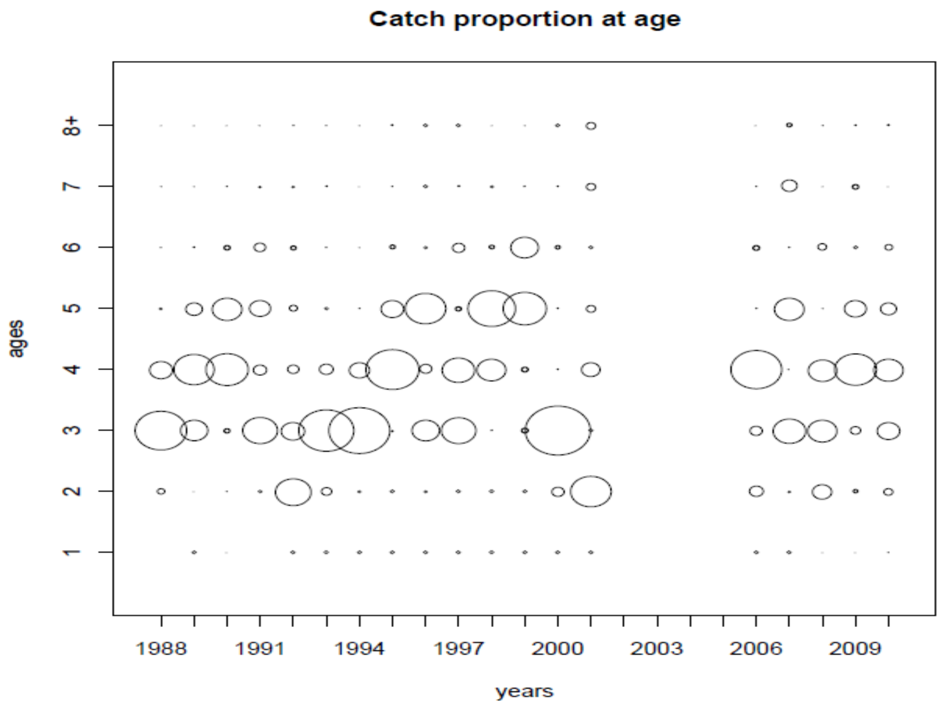


**Figure 4.-** Commercial catch proportions at age

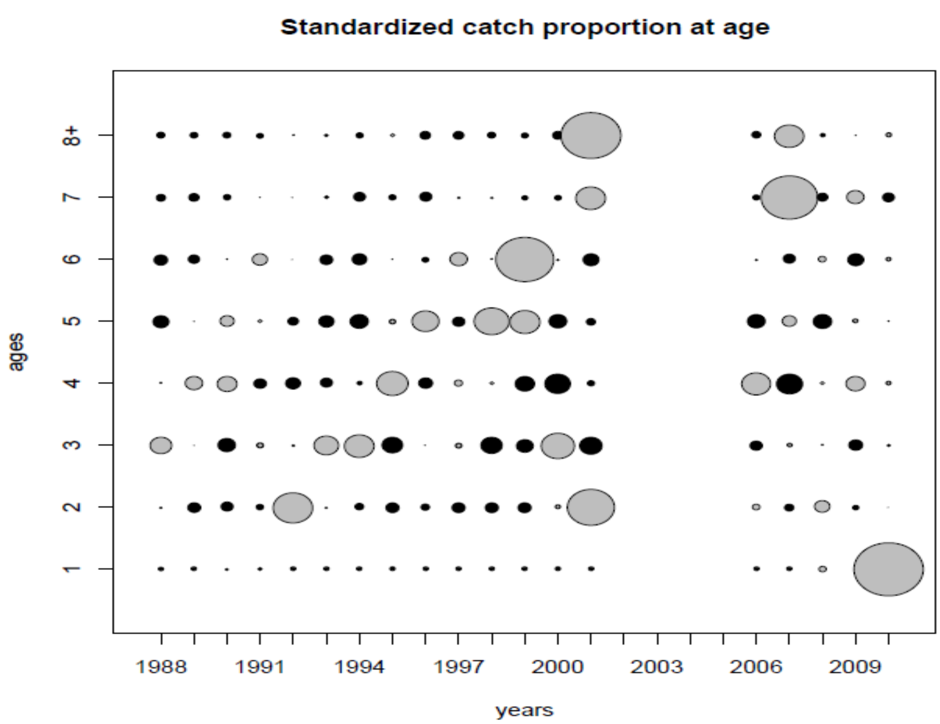


**Figure 5.-** Commercial catch standardised proportions at age. Grey and black values indicate values above and below the average. The larger the bubble size the larger the magnitude of the value.

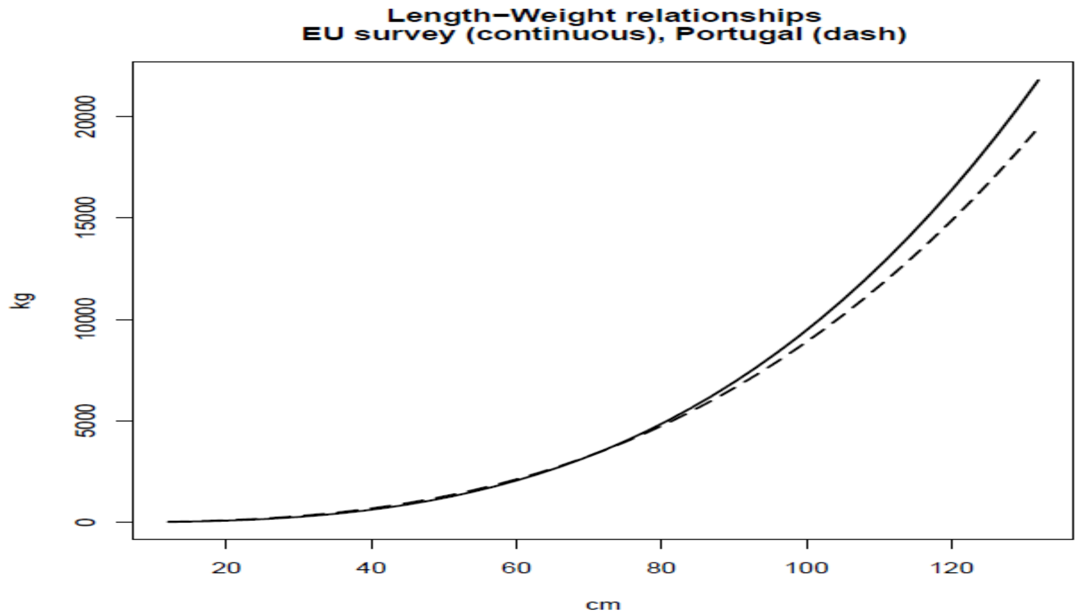


**Figure 6.-** Length-weight relationships for commercial and survey catches

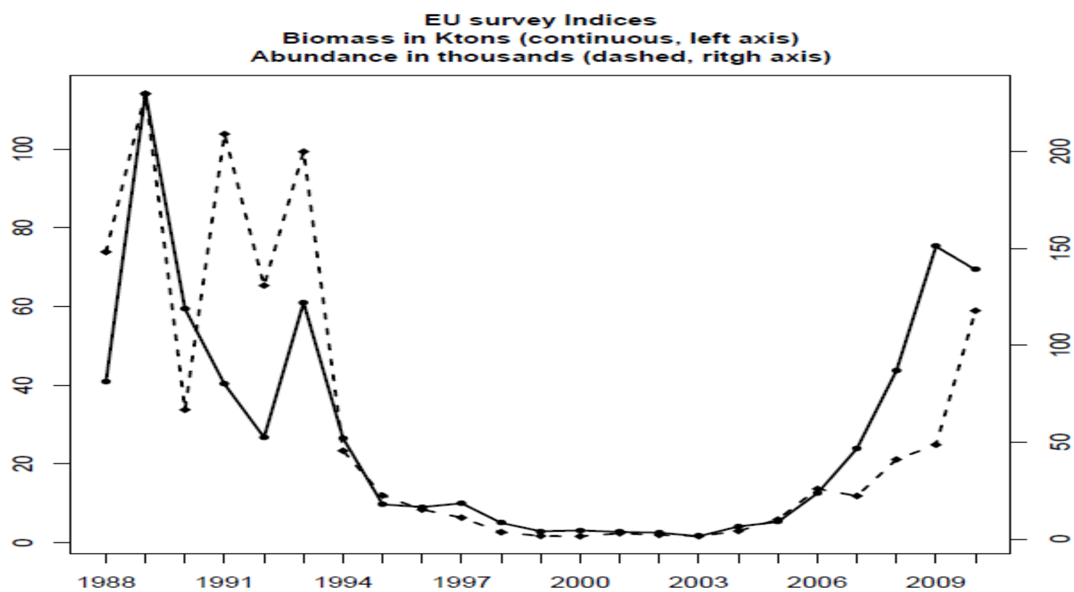


**Figure 7.-** Biomass and abundance from EU survey

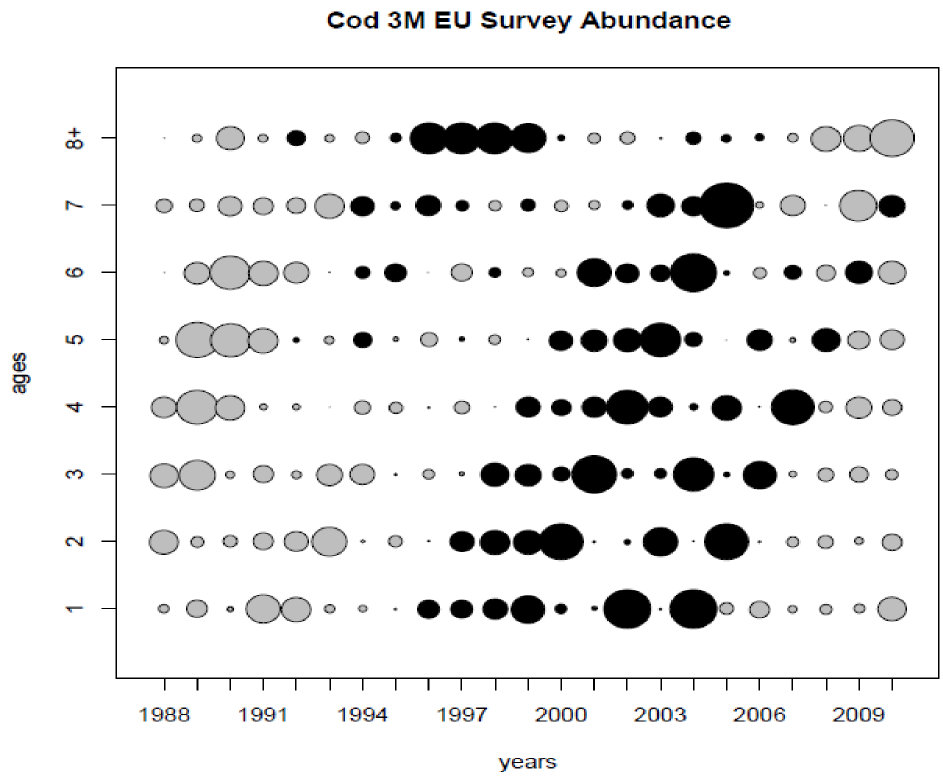


**Figure 8.-** Standardised log(1+Abundance at age) indices from EU survey. Grey and black values indicate values above and below the average. The larger the bubble size the larger the magnitude of the value.

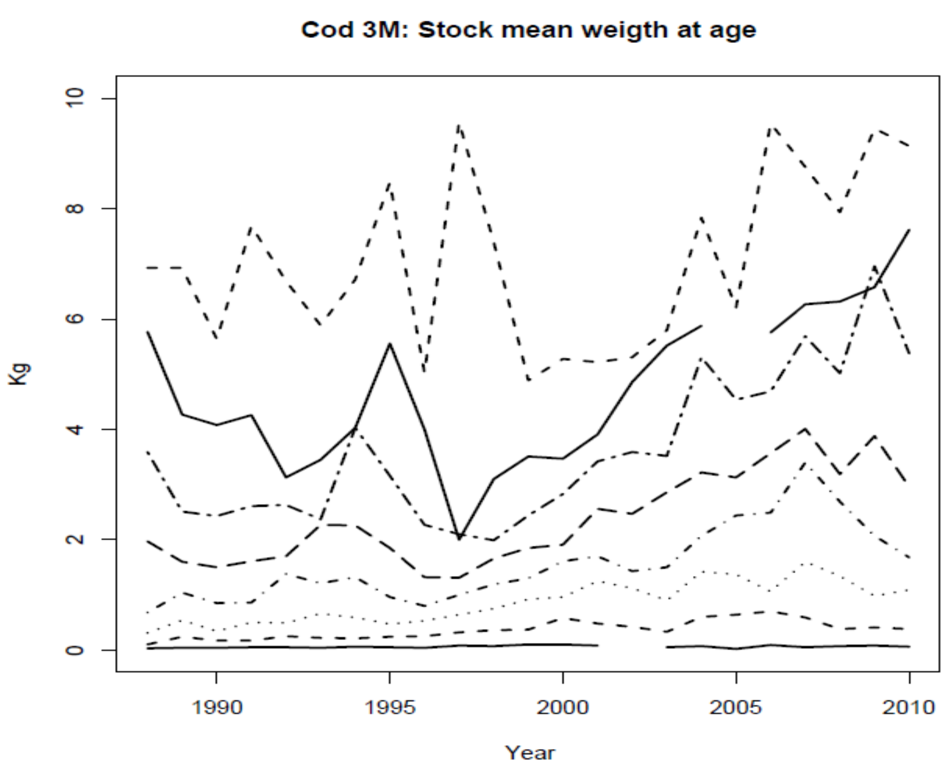


**Figure 9.-** Stock mean weight at age

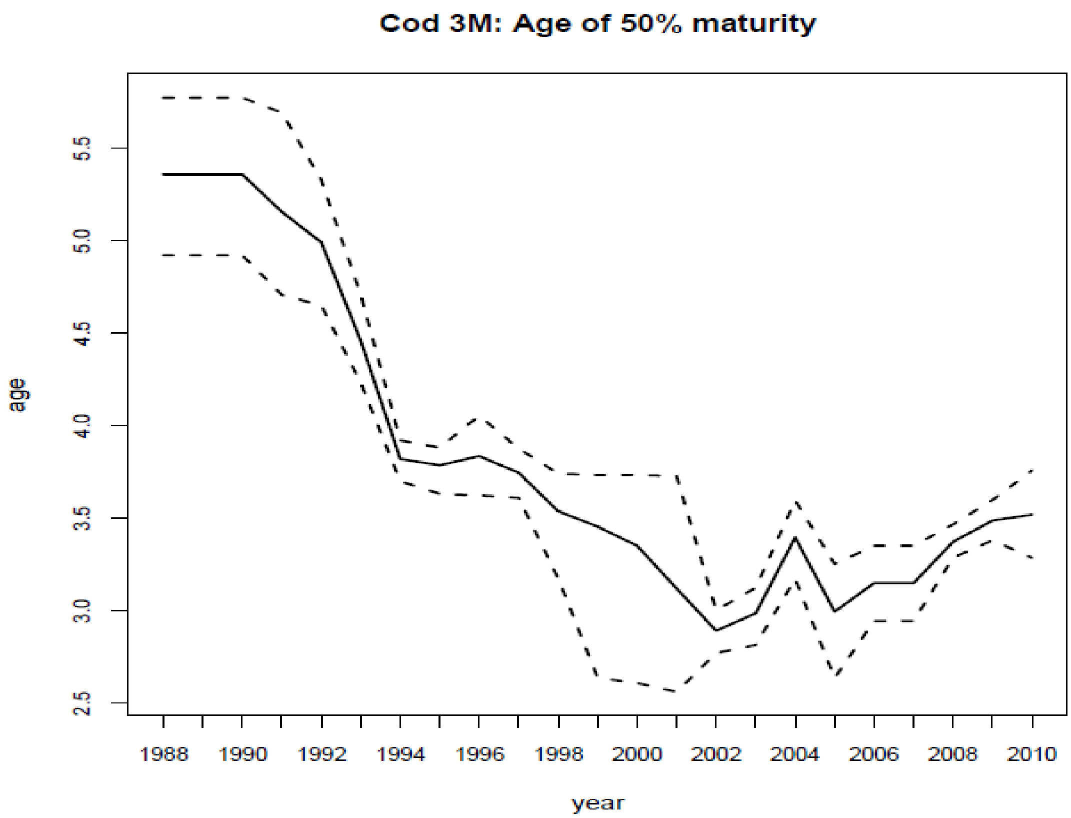


**Figure 10.-** Age at which 50% of fish are mature

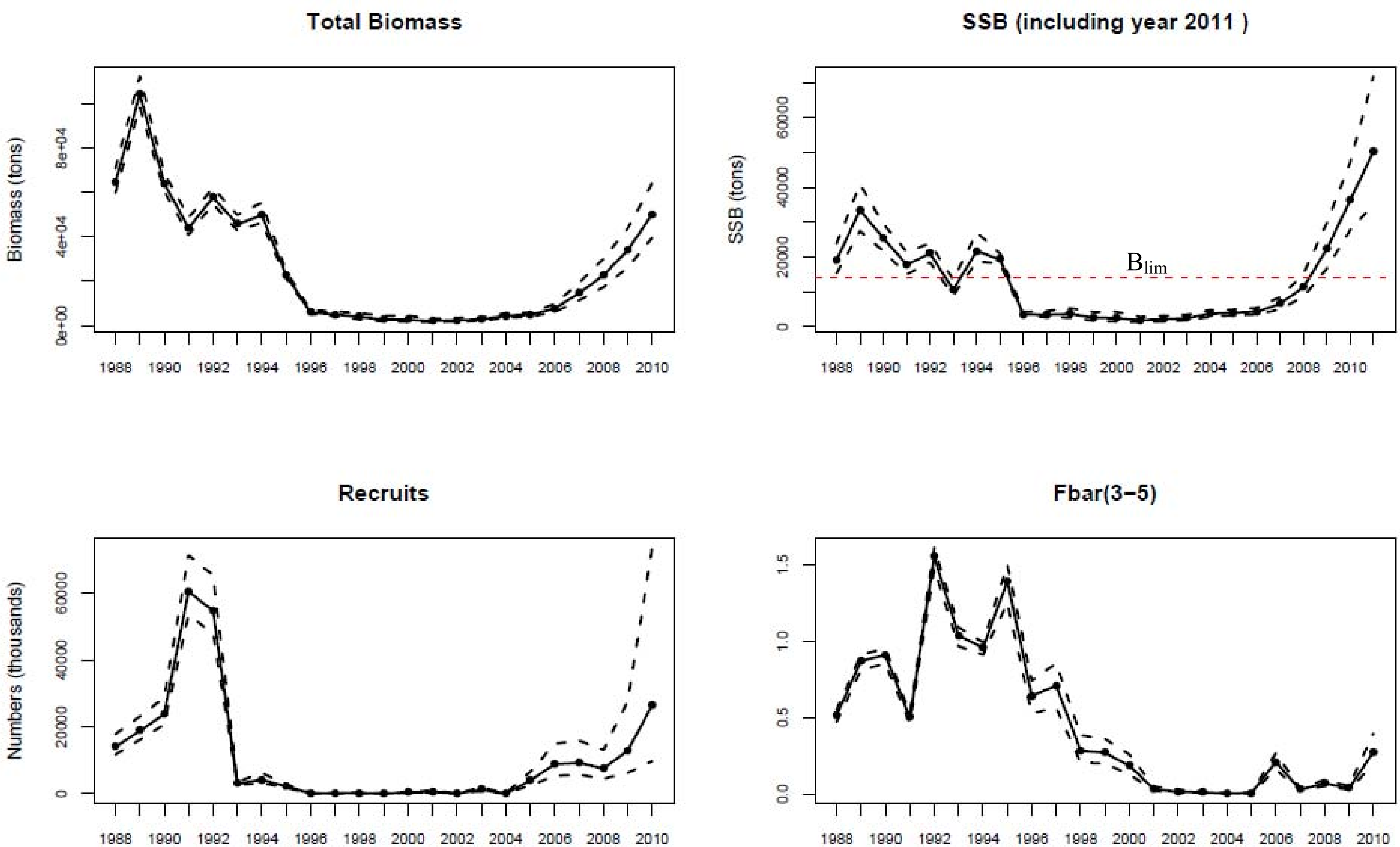


**Figure 11.-** Estimated trends in biomass, SSB, recruitment and Fbar. The solid lines are the posterior medians and the dashed lines show the limits of 90% posterior credible intervals. Red horizontal line in the SSB graph represents $B_{lim}$ = 14000.

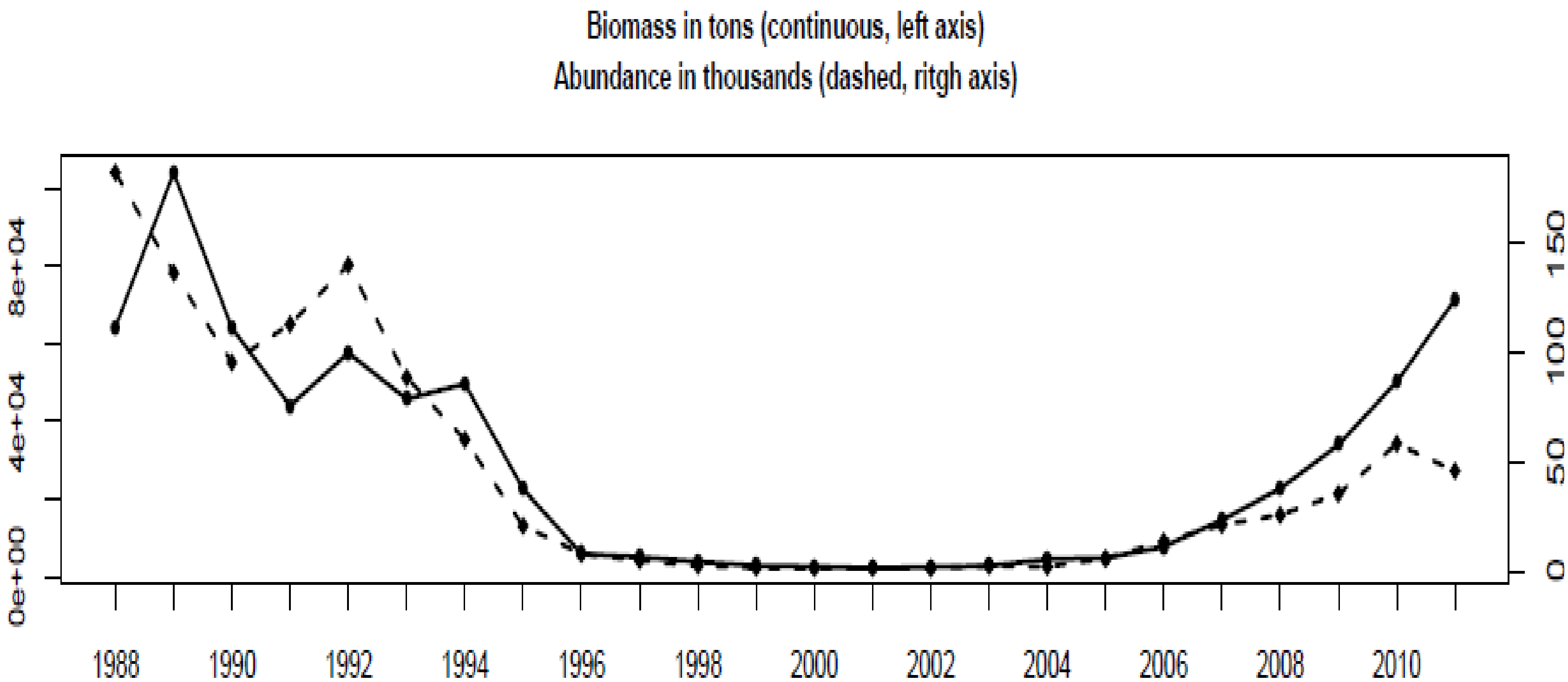


**Figure 12.-** Estimated trends in biomass and abundance.

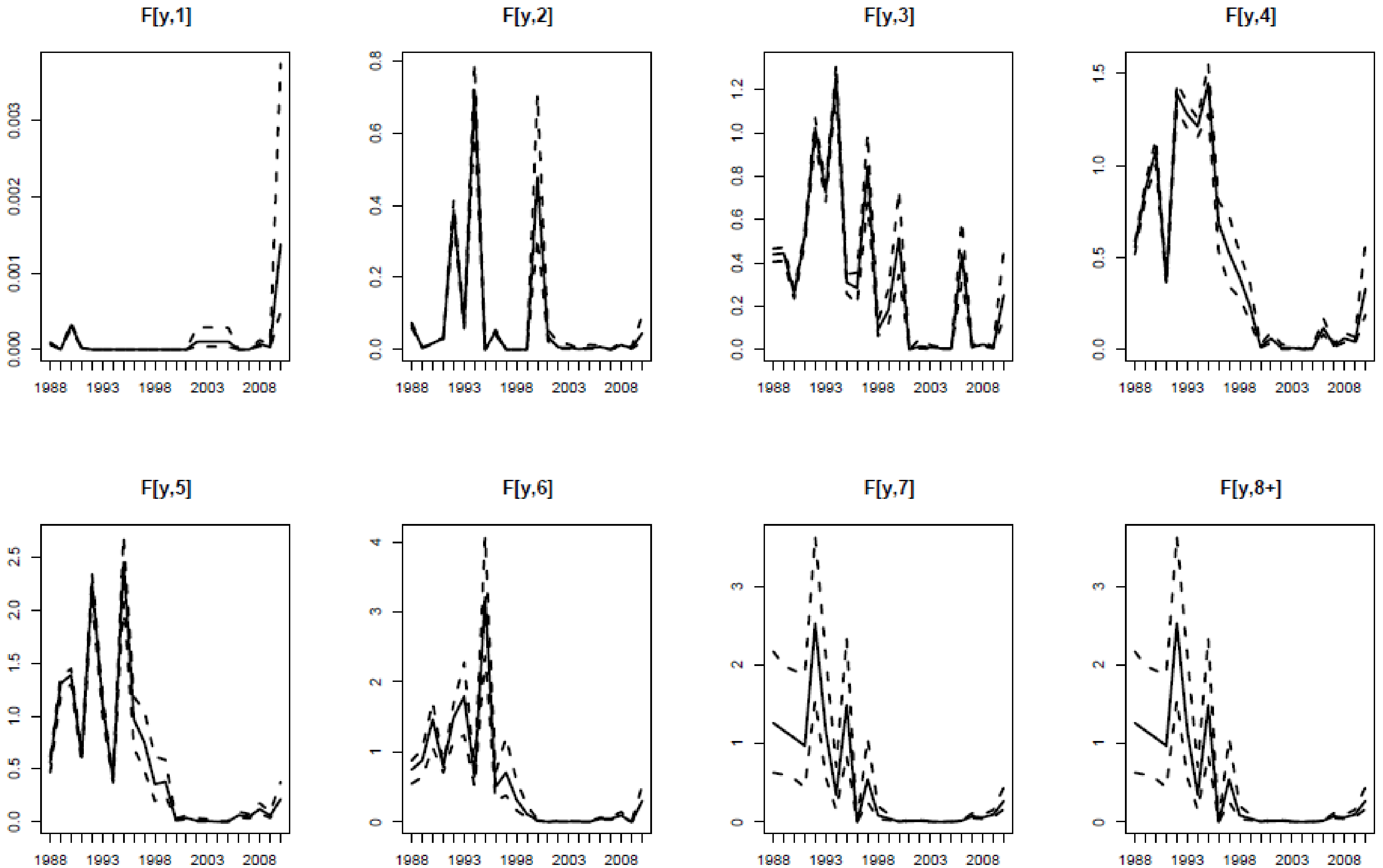


**Figure 13.-** Estimated fishing mortality at age.

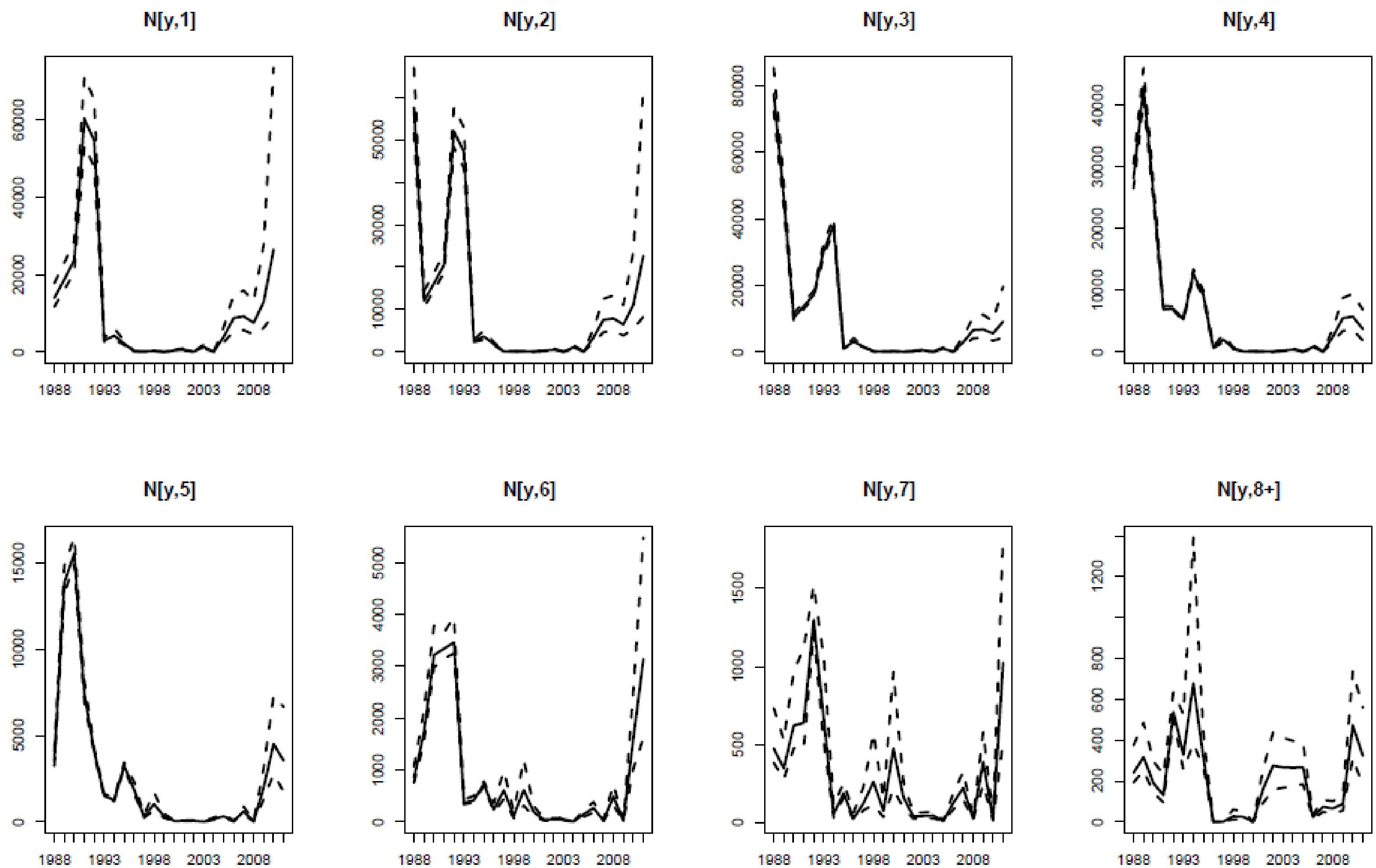


**Figure 14.-** Estimated numbers at age.

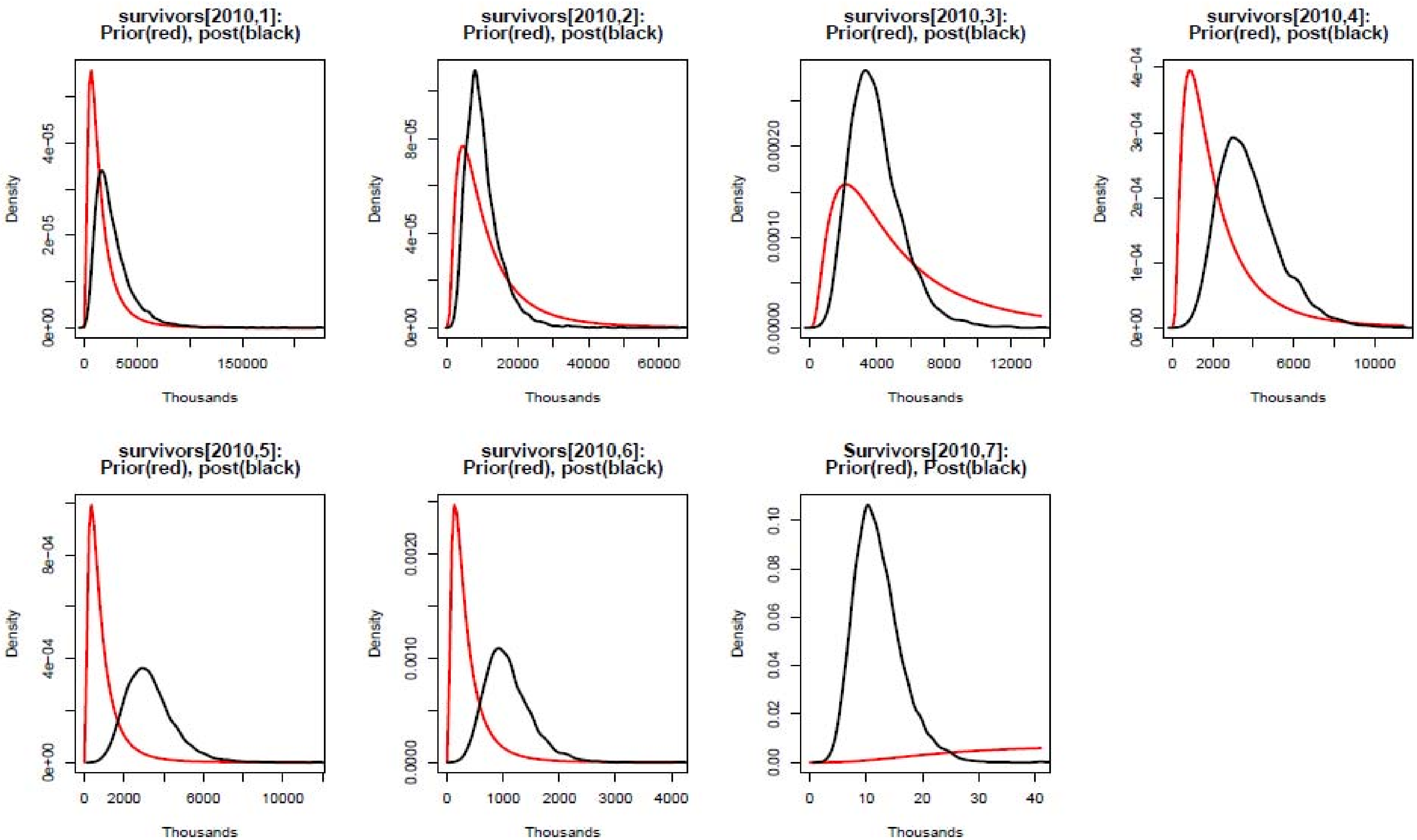


**Figure 15.-** Survivors at age at the end of 2010 (*survivors* (2010,a) are the number of individuals of age a+1 at the beginning of 2011).

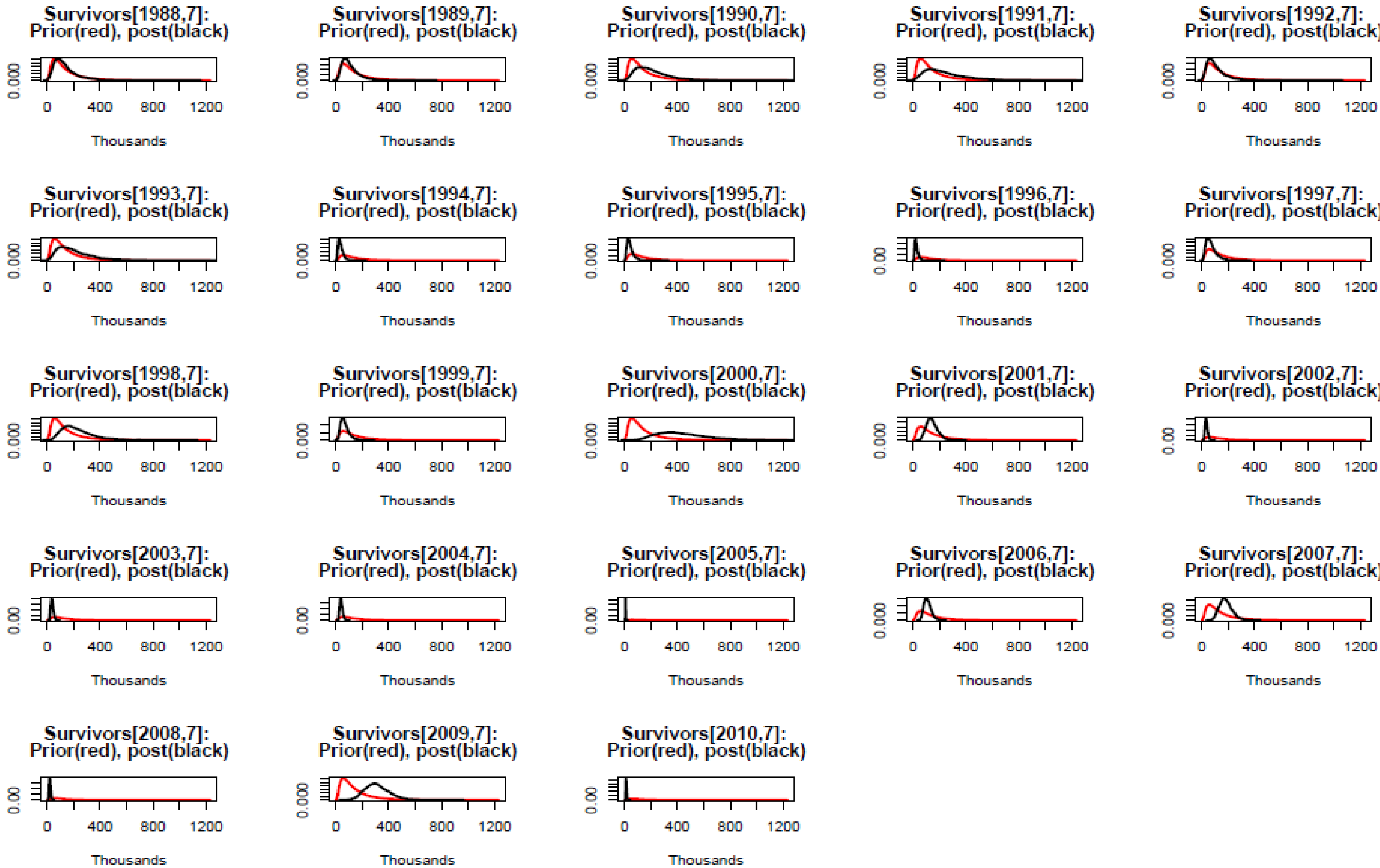


**Figure 16.-** Survivors from age 7 in each year (*survivors* (y,7) are the individuals of age 8 at the beginning of year y+1).

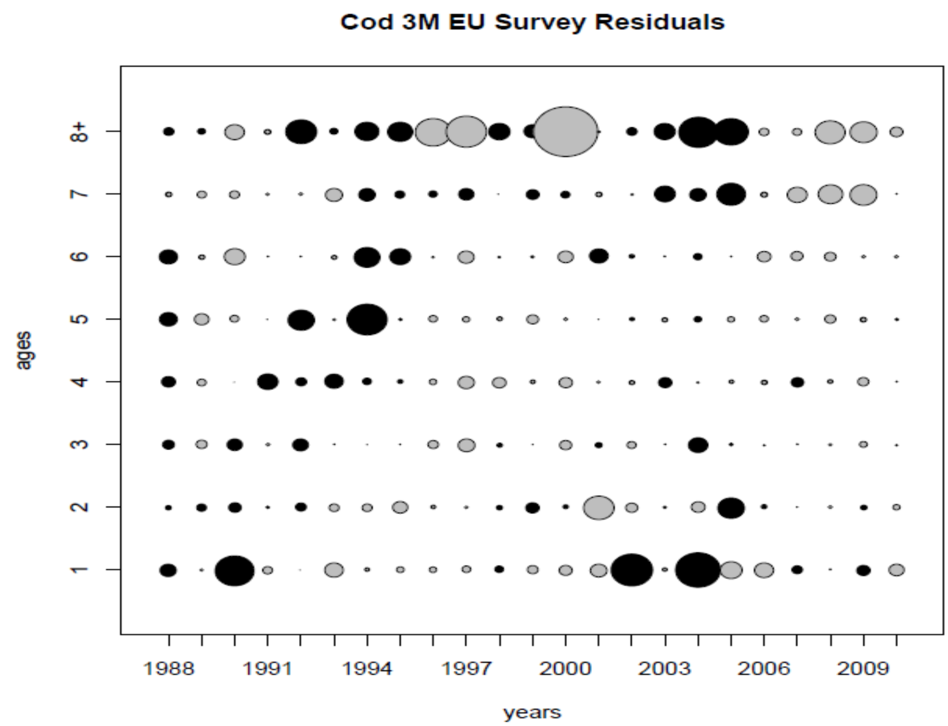


**Figure 17.-** Raw residuals (observed minus fitted value) in logarithmic scale of EU survey abundance indices at age. Grey and black values indicate values above and below the average. The larger the bubble size the larger the magnitude of the value.

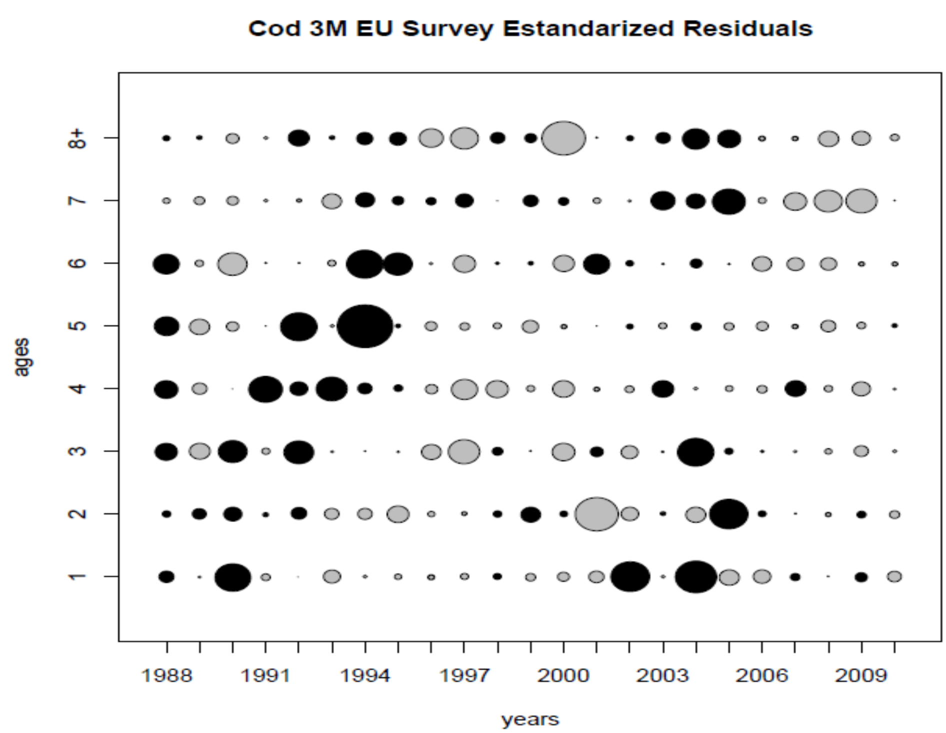


**Figure 18.-** Standardised residuals (observed minus fitted value) in logarithmic scale of EU survey abundance indices at age. Grey and black values indicate values above and below the average. The larger the bubble size the larger the magnitude of the value.

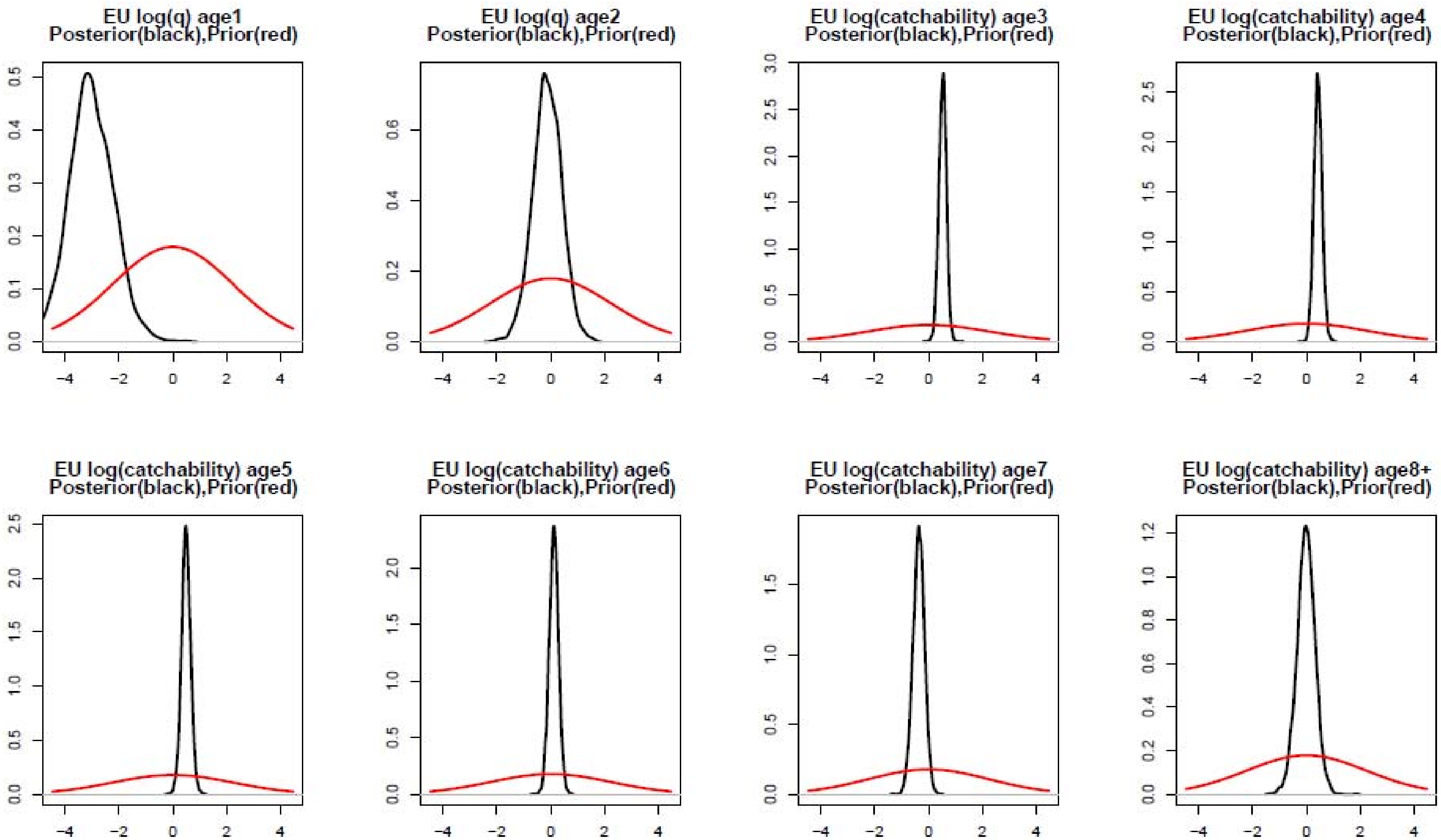


**Figure 19.-** Results for log(q(a)) of EU abundance at age indices.

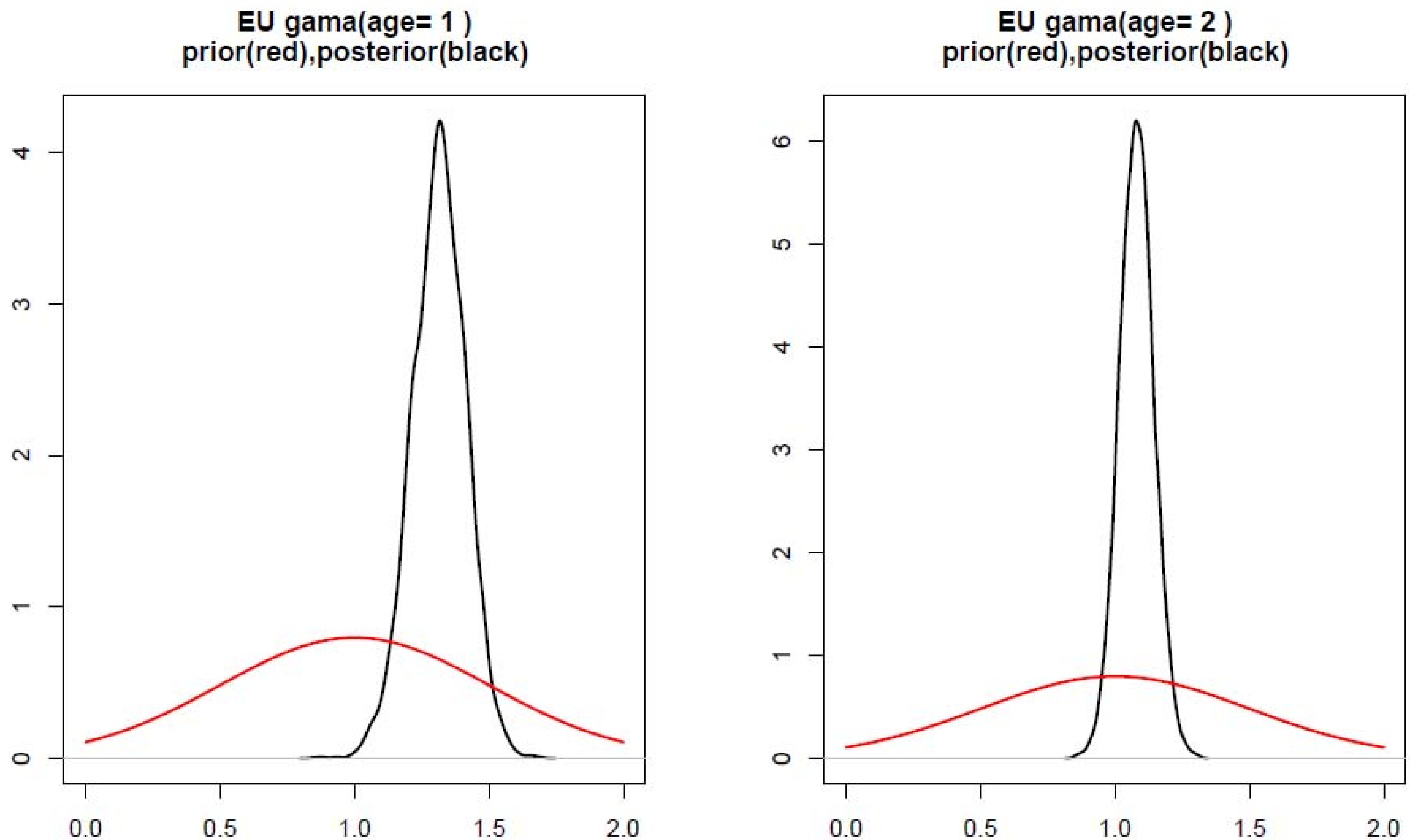


**Figure 20.-** Results for γ(a) of EU abundance at age indices.

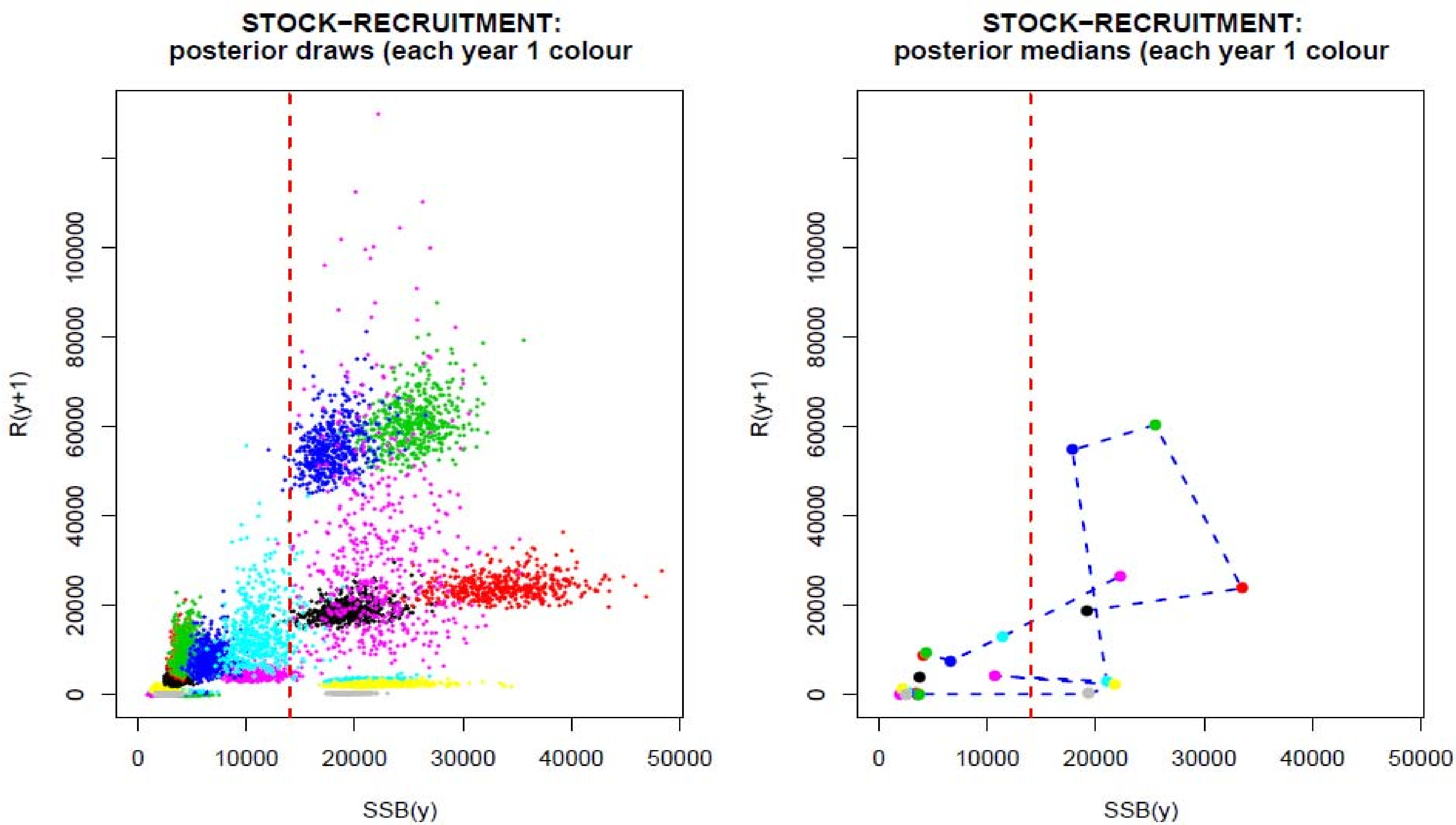


**Figure 21a.-** Stock-Recruitment plots. $B_{lim}$=14000 is shown as the red vertical line.

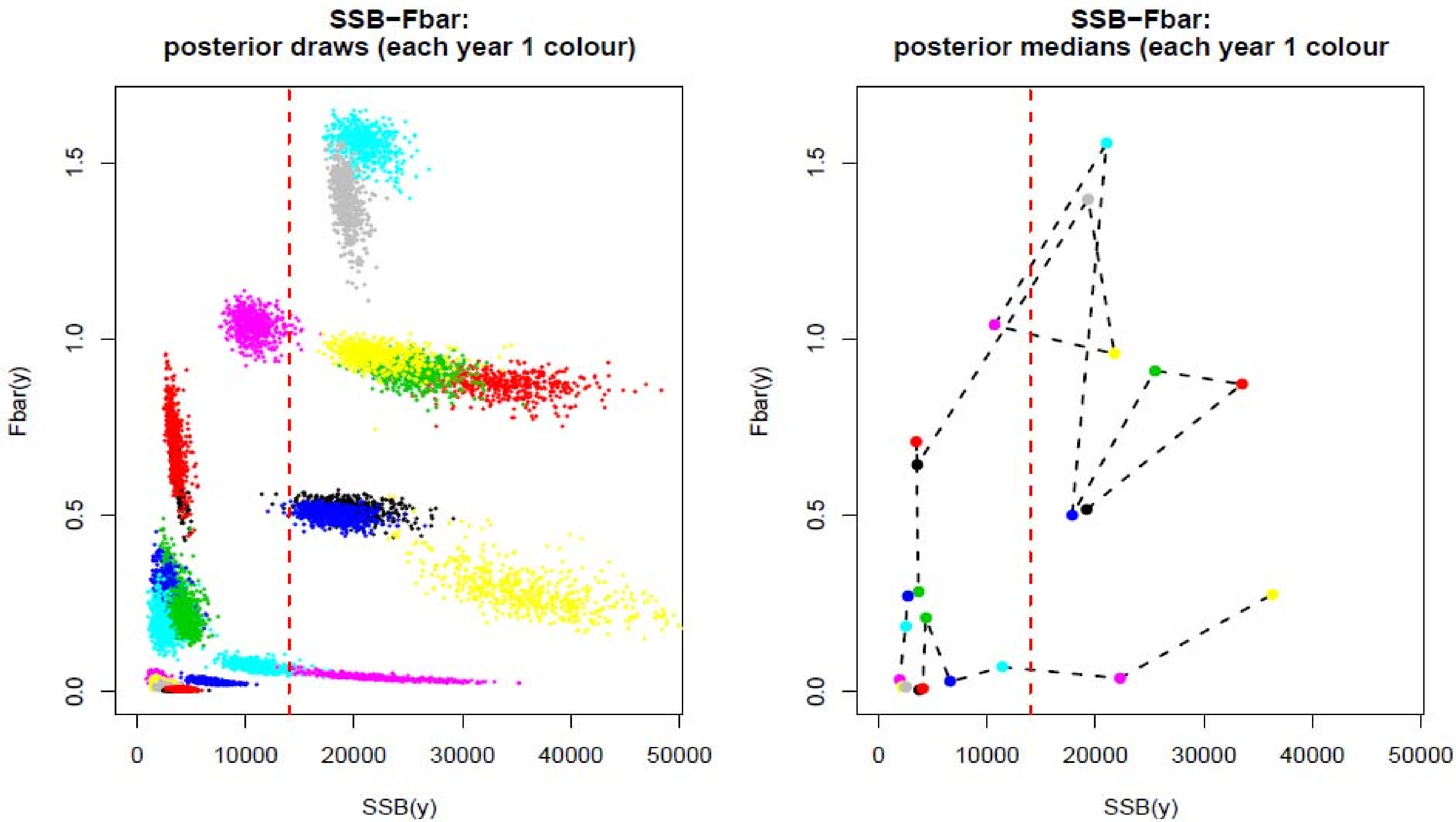


**Figure 21b.-** $F_{bar}$ versus SSB plots. $B_{lim}$=14000 is shown as the red vertical line.

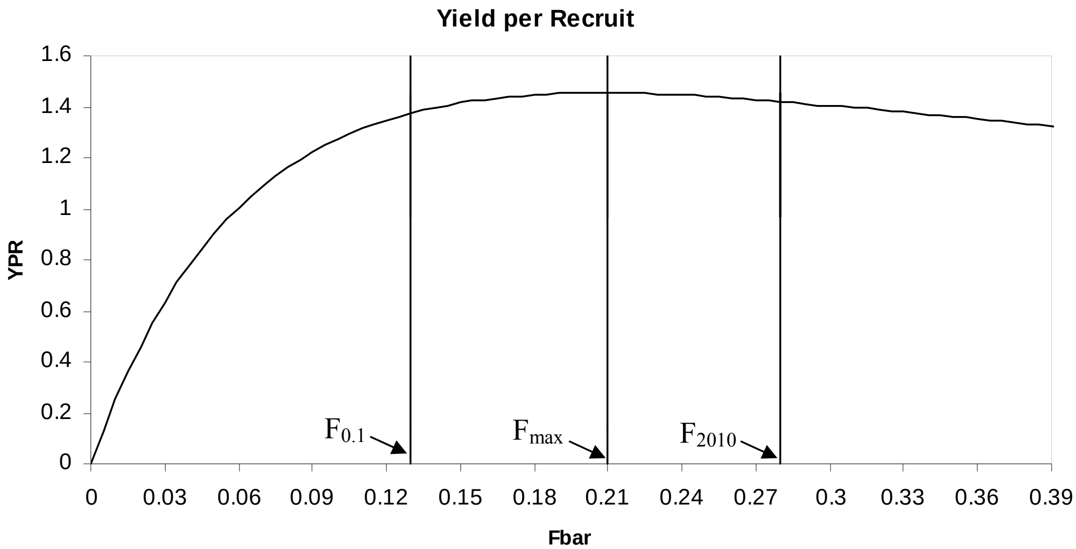


**Figure 22.-** Bayesian Yield per Recruit versus $F_{bar}$. The values of $F_{0.1}$, $F_{max}$ and $F_{2010}$ are indicated

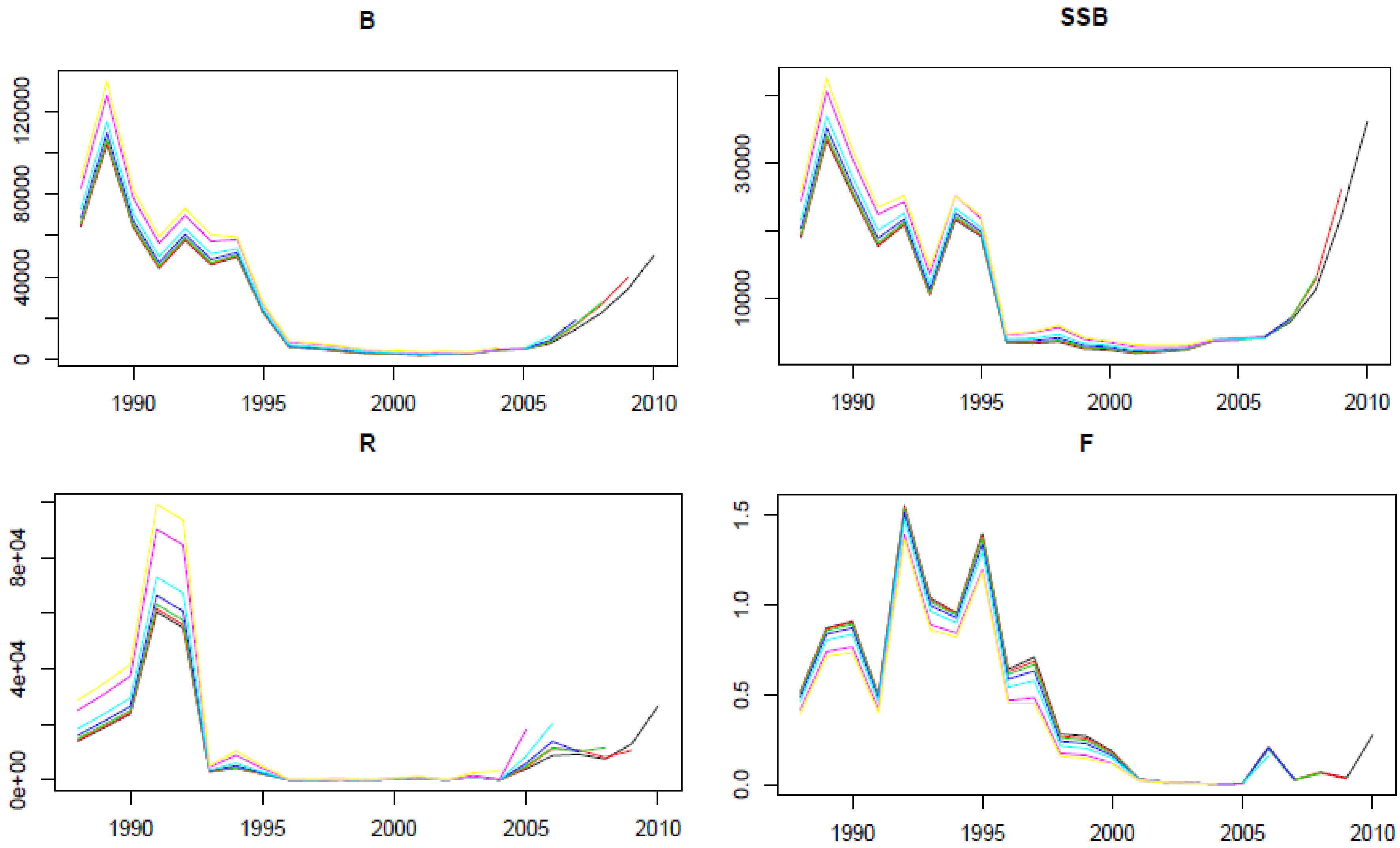


**Figure 23.-** Retrospective patterns.

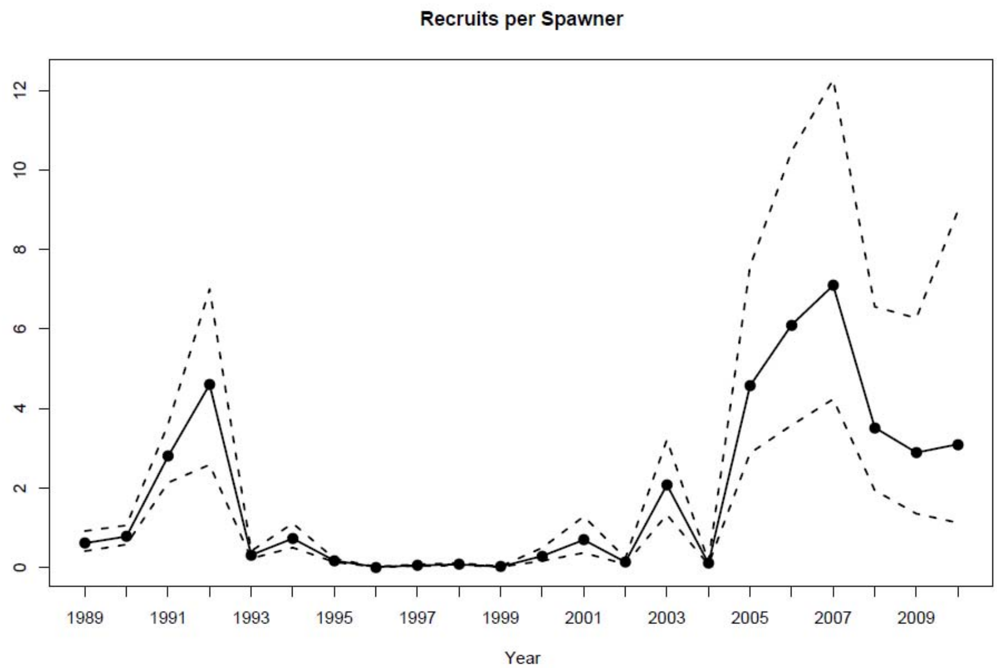


**Figure 24.-** Estimated recruits (age 1) per spawner.

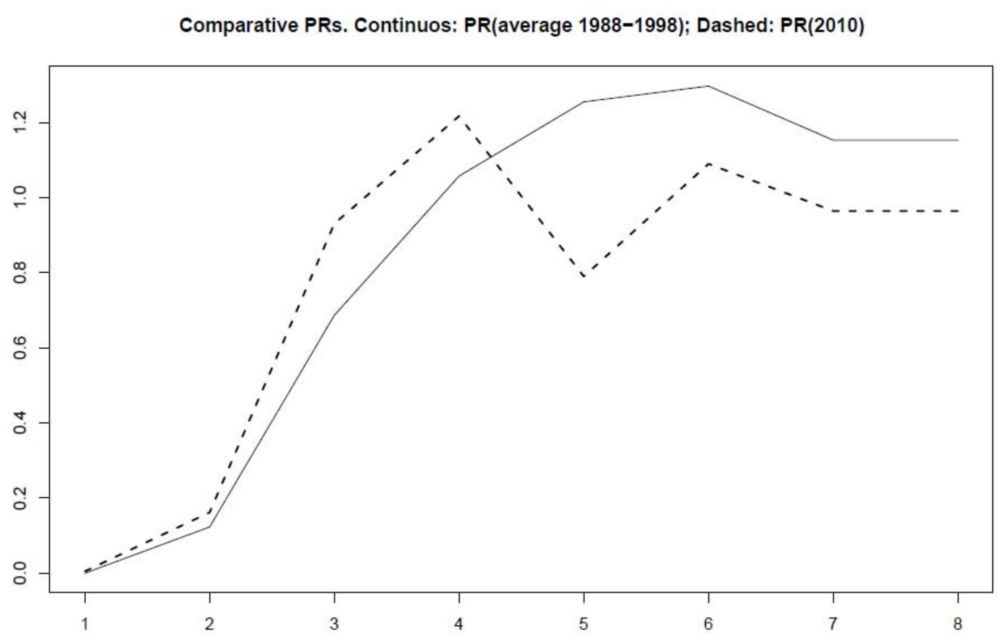


**Figure 25.-** Estimated PRs. Comparative: PR like the mean over the years 1988-1998 and PR as in 2010.

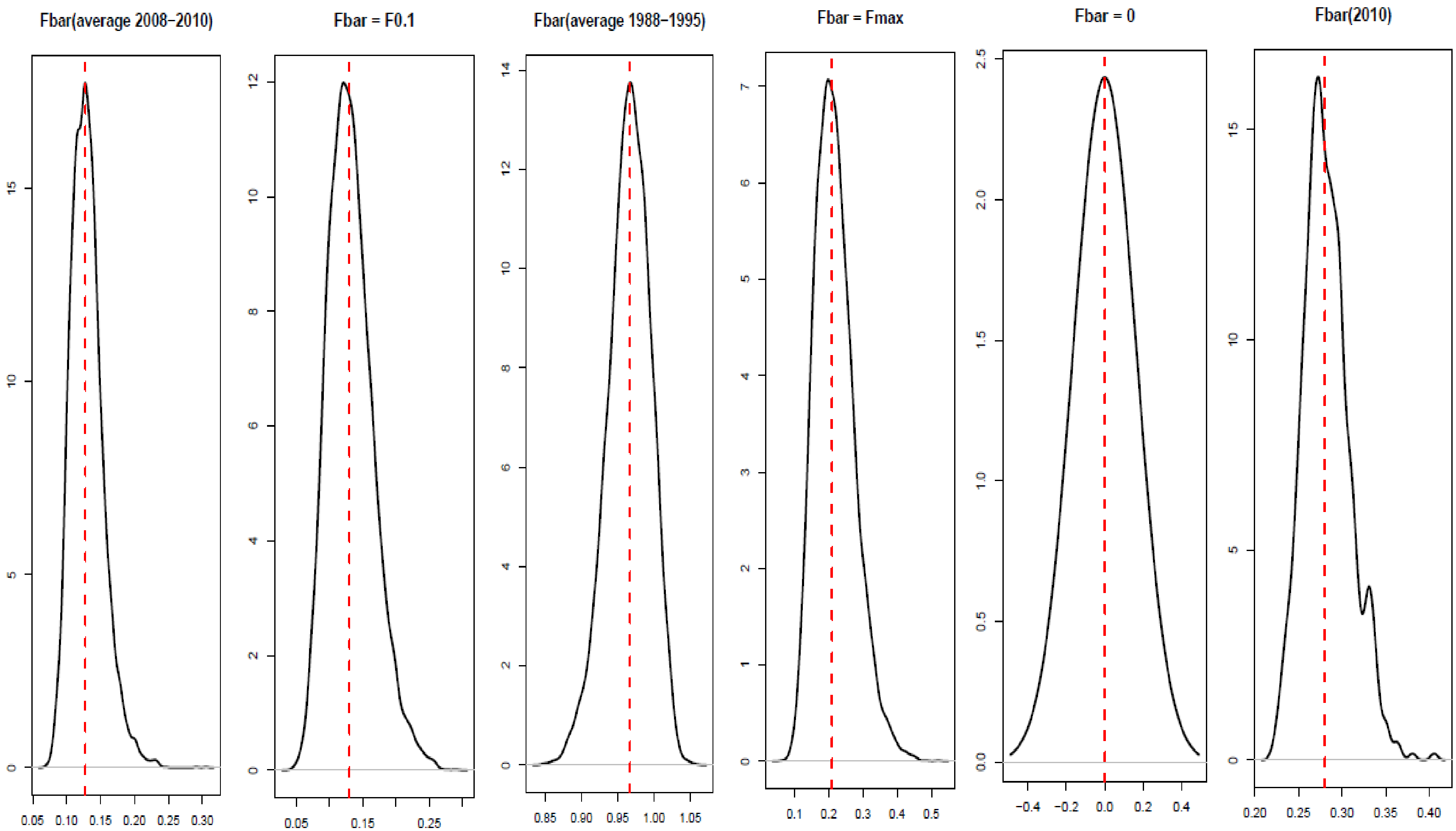


**Figure 26.-** Distribution and median values of $F_{bar}$ over the different scenarios.

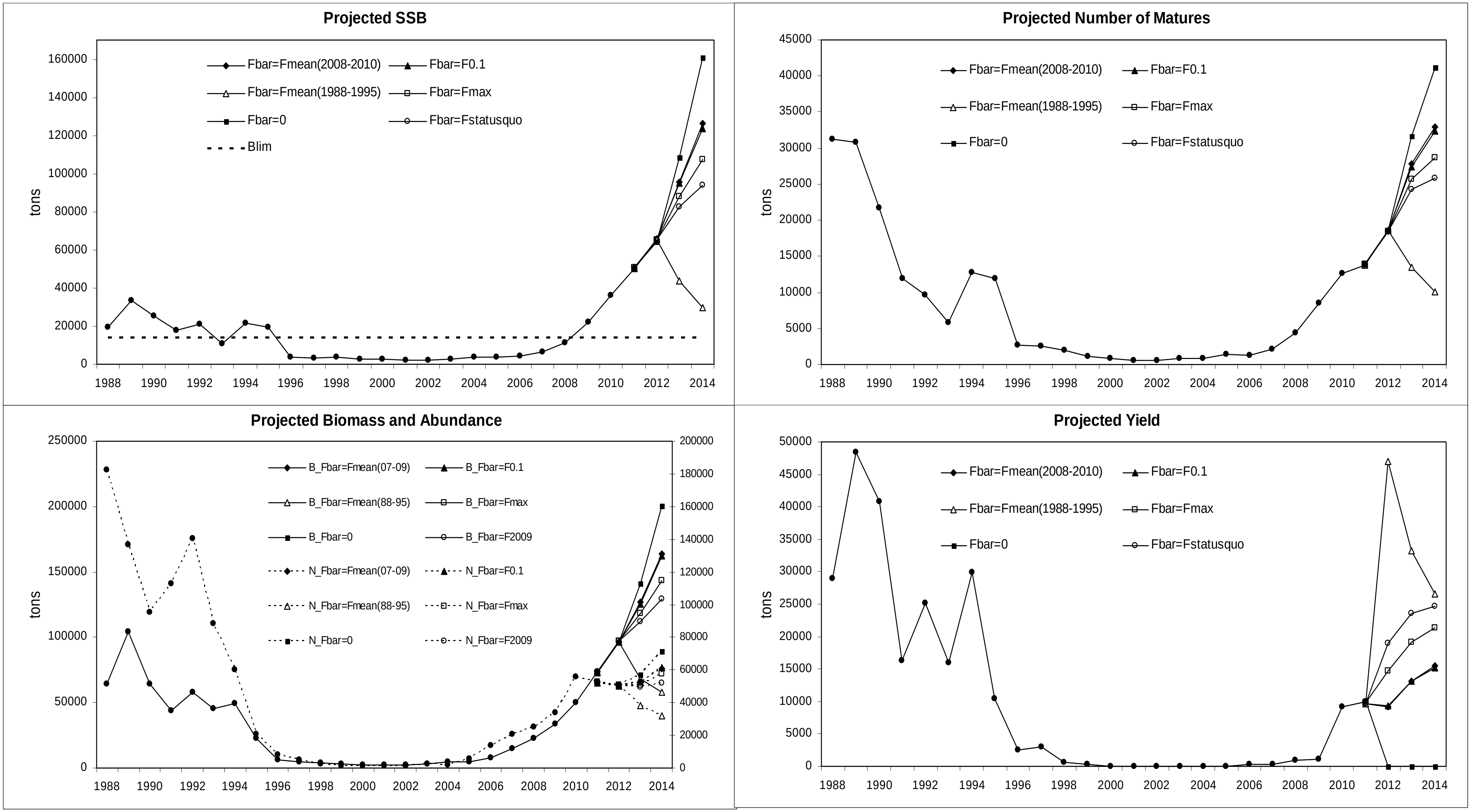


**Figure 27.-** Projections for SSB, number of matures, Total Biomass and Abundance and Yield with different scenarios.