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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. The STACFIS estimations have been used as catch estimations. Results indicate a general increase in SSB since 2005 to the highest value in 2013, reaching a value above B_{lim} since 2009.

Introduction

This stock had been on fishing moratorium from 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, the Spawning Stock Biomass (SSB) was estimated to increase slightly from 2004 to 2006 (Fernández, *et al.*, 2007) while recruitment was estimated above the historical average in 2005 and 2006 which in turn caused an increase of SSB in the 2007-2009 period. Recruitment estimates from 2010 to 2012 (2009-2011 year-classes) are the highest since 1992 (González-Troncoso, 2015).

Since 1974, when a TAC was established for the first time, estimated catches ranged from 48 000 tons in 1989 to a minimum value of 5 tons in 2004. Annual catches were about 30 000 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 below 1 000 tons and from 2000 to 2005 they were lower than 100 tons, mainly attributed to by-catches from other fisheries. Estimated commercial catches in 2006-2009 were between 339 and 1 161 tons (Table 1 and Figure 1), 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 5 500 tons of catch in 2010. With the results of the 2010-2015 assessments TACs for 2011-2017 of 10 000, 9 280, 14 113, 14 521, 13 795, 13 931 and 13 931 tons were established. The STACFIS estimated catches for 2010 was 9 291 tons, which almost doubled the TAC. In 2011 and 2012, catches estimated from the model (medians) were 13600 and 13230 tons. The STACFIS estimated catches for 2013-2016 were 13 985, 14 290, 13 785 and 14 023 tons, respectively.

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, catches between 2002 and 2005 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 was 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), having been used since then in the assessment of this stock.

An assessment of this stock using the Bayesian model used last years is presented. A B_{lim} of 14 000 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

Total Catch

In 2015 there were catches of 3M cod from EU-Estonia, EU-Portugal, EU-Spain, Faroe Islands (Denmark), Norway, Russia and United States with a total amount of 13 785 tons from the STACFIS data. In 2016 there were catches of this stock from Cuba, EU-Estonia, EU-Portugal, EU-Spain, EU-UK, Faroe Islands (Denmark), Norway, Russia and United States (Table 1, Figure 1).

To 2010 scientific catches were used; in 2011 and 2012, a prior over the total catch was applied (see Assessment Methodology).

In 2013 some flag states significant in the Div. 3M cod fishery did not submit their 2013 STATLANT 21A data before the start of the meeting, so STATLANT 21A could not be compared to other catch estimates for 2013. Scientific Council analyzed the CPUEs resulting from Daily Catch Reports (DCR) of 3M cod for the period 2011-2013. These CPUEs were compared with the available scientific data. The results of this comparison show significant differences in 2011 and 2012 and a decrease of such differences in 2013. Based on these results, Scientific Council decided to use total catches from the DCR in 2013 (13 985 t), maintaining the model catch estimation for 2011 and 2012.

In 2014 all the significant countries in this fishery submit the STATLANT 21A on time (although it was provisional for Faroe Islands). For the countries with no STATLANT 21A, the DCR data was taken. A total of 14 290 t of catch was set as the best available STACFIS catch to run the assessment.

In 2015 the DCR data was used. For 2016 a method developed by the WG CDAG was used (NAFO, 2016).

Length distributions

In 2015 length sampling of catch was conducted by EU-Estonia (SCS 16/08), EU-Portugal (SCS 16/09), EU-Spain (SCS 16/05), Faroe Islands (L. Ridao, Personal Communication) and Russia (SCS 16/10). Length frequency distributions from the commercial catch and from the EU survey (Alpoim and González-Troncoso, 2016) are shown in Figure 2 (A).

EU-Estonia has measured 303 individuals in a range of 32-109 cm, a mode in 57 cm and mean of 58 cm. The sample of EU-Portugal contains 9290 individuals measured within 24-111 cm with two modes, one in 39 cm and another one in 48 cm. The mean length of this sample was at 48 cm. EU-Spain has a 6429 individuals sample in a range of 18-118. The modal length is 57 cm and the mean length 56 cm. Faroe Islands have two different types of vessels in this fishery, trawlers and longliners. For the trawlers a total of 4196 individuals were measured between 33 and 131, whit a mode of 54-57 cm and a mean length of 60 cm. The longliners measured 956 individuals with lengths among 27-131 cm, reaching the mode at 57-60 cm and a mean at 70 cm, quite highest than for the rest of the fleets. The number of sampled individuals for Russia was 1478 between 44 and 122 cm. The mode of this length distribution is between 54-60 cm and the mean is 66 cm. The mean length of the total commercial catch is at 55 cm. The EU survey has a mode at 42 cm, followed with another mode in 24 and a mean length of 46 cm. The range is from 12 to 129 cm.

In 2016 length sampling of catch was conducted by EU-Estonia (SCS 17/09), EU-Portugal (SCS 17/05), EU-Spain (SCS 17/04), EU-UK (Andrew Kenny, Personal Communication), Faroe Islands (SCS 17/06) and Russia (SCS 17/11). Length frequency distributions from the commercial catch and from the EU survey (Casas and González-Troncoso, 2017) are shown in Figure 2 (B).

EU-Estonia has measured 217 individuals in a range of 25-71 cm, a mode in 54 cm and mean of 53 cm. The sample of EU-Portugal contains 8219 individuals measured within 27-93 cm with two modes, one in 39 cm and another one in 45 cm. The mean length of this sample was at 51 cm. EU-Spain has a 3127 individuals sample in a range of 25-139. The modal length is 36 cm, followed with another mode at 57 cm, and the mean length 54 cm. EU-UK has a 11754 individuals sample, between 41 and 127 cm. The mode is at 51-54 cm, and the mean at 69 cm. For the Faroe Islands trawlers a total of 1261 individuals were measured between 32 and 124, whit a mode of 60 cm and a mean length of 69 cm. The Faroe Islands longliners measured 3568 individuals with lengths among 43-138 cm, reaching the mode at 60-63 cm and a mean at 73 cm, quite highest than for the rest of the fleets. The number of sampled individuals for Russia was 308 between 40 and 104 cm. Two modes, one at 60 cm and other at 54 cm, can be seen. The mean is 61 cm. The mean length of the total commercial catch is at 56 cm. The EU survey has a mode at 36 cm, followed with another mode in 51-54 and a mean length of 49 cm. The range is from 15 to 132 cm.

In Figure 2 (C) we can see the evolution of the commercial length distribution since 2010, year in which the fishery was reopened. While during the period 2010-2012 the mode of the commercial length distribution was around 54 cm, in 2013 that mode was decreased substantially, being around 42 cm. In 2014 and 2015 the first mode is about 51 and 54 cm respectively, but in both years there is a second mode between 39-42 cm. In 2016 the mode is at 39 cm. This suggests a change in the fish strategy as was pointed out by Iriondo *et al.*, 2014.

The mean length varies between 47 cm in 2013 and 59 cm in 2012.

<u>Catch-at-age</u>

Catch-at-age is presented in Table 2. Data from 1972 to 1987 were taken from the 1999 assessment, in which a review of those data was made (Vázquez *et. al*, 1999). 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 2009-2011 only from the Portuguese commercial data and was applied to the total commercial length distribution. In 2012 otoliths were no collected by the Portuguese fleet, and although a commercial ALK from the Spanish fleet was available, it was not used because it was no validated, so the commercial 2011 ALK was applied to the total commercial length distribution. In 2013-2016 there were two available ALKs for commercial length distribution, one from Portugal and the other from Spain, but as they have not been validated yet, the 2013-2016 survey ALKs were used respectively. In 2011 and 2012, as no consistent catch is available, the percentage of each age is presented.

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 3 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 is comprised of 3-5 years age cod, although in the last two years a shift to the oldest ages can be seen. In years 2006, 2009 and 2014 catches containing mostly age 4 individuals and age 3 in years 2011, 2012 and 2013. In 2007 the greatest presence was at ages 3 and 5 and at ages 3 and 4 in 2008 and 2010. In 2015 age 6 was the most fished, and in 2016 age 5.

Figure 4 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. The biggest circle corresponds to the recruitment (age 1) of year 1987, the biggest caught, by far, of the entire series. But the corresponding cohort was weak. It is remarkable the catch over the recruitment in some of the last years. In 2013, all the values are negative except age 3, with a quite large positive value. In 2014 the biggest value is at age 4, being the values at ages 1-3 large and negative and at ages 5-8 very small and positive. In 2015 all the values are negative until age 6, being 6-8+ values quite large. In 2016, the first positive value is at age 5, and the values increase by age, being 8+ the largest in that year.

Mean weight-at-age

There are available data of mean weight-at-age in catch for years 1972-1987 from the 1999 assessment (Vázquez *et. al*, 1999). For 1988-2014, the same data as last year assessment were taken.

For 2015 and 2016, mean weight-at-age has been computed separately for the catch and for the stock, using length-weight relationships from the commercial sampling and from the EU survey, respectively.

In 2015, for the commercial case, there are five length-weight relationships available: EU-Estonia, EU-Portugal, EU-Spain, Faroes Trawler and Faroes longliner. All of them are presenting in Figure 5A with the 2015 survey one. There are not significant differences between the commercial ones. Faroes trawler gives the smallest weights to the same lengths, while Faroes longliners the highest. As the sample with the largest number of individuals sampled is the Portuguese one, this length-weight relationship was applied to the trawl commercial data to calculate weight-at-age in the catch.

There are three length-weight relationships available in 2016: EU-Estonian, EU-Portuguese, and EU-Spanish. All of them are presenting in Figure 5B with the 2016 survey one. There are significant differences between the commercial ones, being the Spanish one very similar to the survey one. Portuguese samples give higher weight to the same lengths and the Estonian one smaller. As the sample with the largest number of individuals sampled is the Spanish one, this length-weight relationship was applied to the commercial data to calculate weight-at-age in the catch.

Results are showed in Table 3 and Figure 6. Since 2007 there is a general decrease in the trend of the mean-weight for the ages between 2 and 7 years old, especially since 2010. Ages 1 and 8+ present a quite stable trend over these years. In 2016 the mean weight in catch for all ages but 3 is lower than in 2014, although the decrease seems to be less marked.

There are some gaps in the series of mean weights in catch due to the lack of individuals to calculate a mean weight. This affects directly the calculation of the biomass. Those gaps were filled using the mean of the previous year and the following year and were incorporated to Table 3 in red.

The SOP (sum over ages of the product of catch weight-at-age and numbers at age) for the commercial catch differs less than 2% from the estimated total catch in the last two years.

Survey data

Canadian survey

Canada conducted research vessel surveys on Flemish Cap from 1978-1985. Surveys were done with the R/V *Gadus Atlantica*, a stern trawler of 74 m in length, fishing with a lined *Engels 145* otter trawl. The surveys were conducted in January-February of each year from 1978 to 1985, using a stratified random design. Fishing sets were usually of 30 minutes duration, over a distance of 1.75 nautical miles, and covered depths between 130 and 728 m. All strata were surveyed each year, with the exception of 1982, when 4 deeper strata were omitted (Brodie and Bowering, 1992).

Survey indices of abundance at age are presented in Table 4. Figure 7 displays the estimated biomass and abundance indices over the time series. From a high value in 1978, a general decrease in both indices can be seen until 1985. 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 was able to detect strength of recruitment and to track cohorts through time very well.

It clearly shows a series of consecutive recruitment failures from 1978 to 1980, leading to very weak cohorts, specially the 1979 one (age 1 at 1980). The 1981 cohort was quite good.

EU survey

The EU bottom trawl survey on Flemish Cap has been carried out since 1988 using a *Lofoten* type gear, 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 1988-2016 are presented in Casas and González-Troncoso, 2017.

Survey indices of abundance at age are presented in Table 5. Figure 7 displays the estimated biomass and abundance indices over time. There are differences between the level of biomass and abundance in the Canadian survey and in the EU one, probably due to the difference in the gear. Biomass and abundance show a high increase since 2005, higher in biomass than in abundance except for 2011, following an extremely low period starting in the mid 1990's. The large number in 2011 is due to a big presence of individuals of age 1. It must be noted that 2009-2010 and 2013 biomass is at the level of the first years of the assessment but abundance in these years 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 a new huge increase can be seen in 2011 and 2012. The abundance in 2011-2012 are the highest of the time series of this survey. In 2013 a new decrease in abundance and biomass occurred, both reaching the level of 2009-2010. In 2014 the biomass increased again reaching the maximum of the time series by far. The abundance increased too but much less, being well below the maximum observed during years 2011-2012. The increase in biomass is due to a big increase in the number of individuals of 3 and 4 years old, those from the 2010-2011 cohorts, and the decrease in abundance to a less presence of individuals of ages 1 and 2 (Casas and González-Troncoso, 2017). In 2015 and 2016 both indices have decreased. The biomass is still at high levels (is approximately twice the mean of the EU series), but the abundance is below the mean abundance of the EU entire series.

Figure 9 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 to 2014 onwards appear to be above average. In 2010-2012 a good recruitment can be seen, especially in 2011, lead to two reasonably good cohorts. 2013 and 2014 recruitment were not as good as in those years, but it is still at the level of the beginning of the recovery of the stock. 2015 and especially 2016 recruitments have failed. Age 8+ in 2014-2016 presented a high value, which indicates the strength of the 2006-2008 cohort.

Mean weight-at-age

Mean weight-at-age in the stock for Canadian survey is not available, so mean weight-at-age in the stock is only available from the EU survey from 1988 to 2016. For the previous years, as the stock change rapidly, it was decided to apply the weight-at-age for catch. As catch has no weight-at-age for the youngest ages (1 and 2), the mean of the EU survey weight-at-age between years 1988-1995 for those ages was taken. The reason for taking those years is that the stock seems to change suddenly its weights-at-age in 1996. The results are showed in Table 6 and Figure 10.

As in the mean weights in catch, there are some gaps in the series of mean weights in stock due to the lack of individuals to calculate a mean weight. This affects directly the calculation of the biomass. Those gaps were filled using the mean of the previous year and the following year and were incorporated to Table 6 in red.

Mean weight-at-age in the stock showed a strong increasing trend from the late 1990's until 2007, being much higher than at the beginning of the series. Since 2008 to 2016 a deceasing trend was observed for all age groups, being very steep in some cases. The biggest difference is from 2011 to 2012, when the weight-at-age for ages 1-2 increased, but decreased substantially for ages 3-8+. Between 2008 and 2016 the mean weights in stock for ages 1-7 decreased among 43% and 71%and all of them are below the mean of the entire series. It is remarkable the low value of weight at age 3 (0.35 kg) in 2014, which is among the lowest of the entire times series. Although it increased slightly since then, it is still very low.

Maturity at age

Maturity ogives from the Canadian survey are available for all the years (1978-1985) and from the EU survey for years 1990-1998, 2001-2006 and 2008-2016. For those years logistic regression models for proportion mature at age have been fitted independently for each year. For years 1983-1985 the fit was no consistent, so those years were omitted for the fit. For 1972 to 1977, the 1978 maturity ogive was applied. The 1982 maturity ogive was taken for 1983 to 1987. 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 7 and Figure 11. It can be seen that the percentage of matures in all ages decreased since 2006 to 2011, especially in 2011. This fact, along with the decreasing mean weight at age, is consistent with a stock in a recovery process, with a slower growth and maturing. In 2012 the percentage in ages 4 and 5 increased, as in all ages in 2013 (especially for ages 3 and 4). This is not consistent with the decrease in the mean weight for all ages. Maturity for all age groups declined sharply from 2013 to 2016.

Figure 12 displays the evolution of the a50 (age at which 50% of fish are mature) through the years (estimate and 90% uncertainty limits) and the median value is presented in Table 7. The figure shows a continuous decline of the a50 through time, from above 5 years old in the late 1980’s to below 3 years old in 2002 and 2003. An upward trend is present in a50 since 2005. From 2005 to 2011 a50 increased monotonously from 3 to 4.13 years respectively and it declined in 2012 and again in 2013 to 3.39 years due to the increase in the percentage of maturation on all the ages. In 2014-2016 it increased substantially to 5.17 years old in 2016, around the maximum in the time series.

Assessment methodology

The Bayesian model used last years was updated with 2015 and 2016 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 approved assessment.

In 2011 and 2012, due to lack of information about catches, Scientific Council decided to incorporate a new prior for the total catch in 2011 and 2012. In 2011, the effort in the major fleets has increased 40% approximately regarding 2010 effort and the 2010 catch was 9 192 tons, so it was decided to fit a prior to 2011 catch with a median value of approximately 12 800 tons and a standard deviation that allows the catch to move between 9 905 and 16 630 tons (95% confidence interval). The chosen prior was a lognormal. In 2012 the TAC was slightly below the 2011 TAC and the effort was virtually the same, so no evidences of change in the catch of 2012 with regards to the catch of 2011 exists, therefore the same prior was taken. The priors for 2011 catch and 2012 catch are independent.

The inputs of the assessment of this year are as follow:

Catch data for 45 years, from 1972 to 2016

For 2011: $TotalCatch(2011) \sim LN(median = 9.46, sd = 0.1313)$

For 2012: $TotalCatch(2012) \sim LN(median = 9.46, sd = 0.1313)$

Years with catch-at-age: 1972-2001, 2006-2016

Tuning with Canadian survey for 1978 to 1985

EU survey for 1988 to 2016

Ages from 1 to 8+ in all cases

Catchability analysis

Catchability dependent on stock size for ages 1 and 2

Priors over parameters:

Priors over the survivors:

For (2016, a), a=1,…,6 and (y, 7), y=1972,…, 2016

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

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

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

where CW_{mod} is arised from the Baranov equation

cvCW=0.05

Prior over the survey abundance at age indices:

For a=1,…,8 and y=1978,...,1985 (Canadian survey) and y=1988,…,2016 (EU survey)

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

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

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

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

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

where I is the 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, five year retrospective plot was made.

Two years projections were made with four 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 8 and Figure 13. Taking a recruitment for 2017 as the 2013-2015 recruitments mean, and the mean weight in catch, mean weight in stock and maturity ogive as in 2016, total biomass, SSB and recruitment at the beginning of 2017 is estimated and presented in the tables and figures.

Total biomass had an increased trend since 2006 until 2013, reaching the same level as before the collapse of the stock in the mid 1990´s. Since then a decreasing trend can be observed, being in 2016 slightly below the 2010 value.

The results for SSB 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 since 2010 has been more or less stable around the highest values of the time series although with a slight decrease since 2014. This high values are probably due to the increase in the percentage of maturity in all ages, that compensates the decrease in the mean weight in all ages, and to the incorporation of the strong 2010 year class which leads in a higher number of individuals.

Recruitment had an increasing trend from 2005 to 2011, being the 2009, 2010 and 2014 values at the level of the mean recruitment of the period and the 2011 and 2012 values above it. Since 2013 the recruitment has been decreased substantially and in 2016 is above the 2005 value. Take into account that the actual recruitment levels for last years can not yet be precisely estimated (wide uncertainty limits) (Figure 13 and Table 8).

F_{bar} (mean for ages 3-5) was estimated at very low levels in the period 2001-2009, although an unusual high value has been estimated for 2006. In 2010, when the fishery was reopen, the F_{bar} has increased up to 0.26, although the established 5 500 tons TAC corresponded to a target F_{bar} around 0.14. In 2011, with a TAC of 10 000 tons corresponding to a target F_{bar} around 0.13, a F_{bar} of 0.29 was estimated. In 2012 F_{bar} was estimated at 0.23, while the TAC of 9 280 was established under a F_{bar} of 0.13. In 2013 the TAC was increased almost 50% with respect to 2012 TAC, and the F_{bar}=0.27 is twice the F_{bar} approved in 2012. For 2014 the TAC remained stable (14 113 tons) corresponding to a F_{bar}=0.14, while the one estimated by the assessment was F_{bar}=0.26. From a decrease in 2015 up to F_{bar}=0.18, a new decrease in 2016 (F_{bar}=0.28) can be observed. Table 9 and Figure 14 provide more detailed information on the estimated F-at-age values, indicating that the increase in F_{bar} in 2006 is mostly due to a high fishing mortality at age 3 ($F_{3,2006}$=0.449). Since 2010 fishing mortalities have remained stable at around F_{bar}=0.25. In 2010 the highest fishing mortalities are in ages 4 and 6, and from 2011 to 2014 in 6-8+. In 2015 the highest fishing mortality is at age 6, following by ages 7-8+. In 2016 the highest fishing mortality is in ages 7-8+. Figure 15 shows the PR along the years, calculated as the ratio of fishing mortalities to F_{bar}. Figure 16 shows the PR for the years since the reopening of the fishery (2010-2016) and Figure 17 the mean of the three last years (2014-2016) PR *versus* the 2016 PR. The 2015 PR is quite different from those from the rest of the years, and in 2016 most of the fishing mortality is comprised for ages 7 and 8+. Some differences can be observed between the last three years PR and the 2016 PR.

Figure 18 shows total biomass and abundance by year. Except in the first years of the assessment and the period 1985-1989, in general there is a good concordance between biomass and abundance, although in last years biomass has increased more than abundance. It must be noted that, although SSB in last years is within the maximum of the series (Figure 13), total biomass and abundance have not reached yet the highest historical level. Total biomass is among the mean of the total period biomass, but abundance is well above (around half the mean).

Estimates of stock abundance at age for 1972-2017 are presented in Table 10 and Figure 19. Abundance at age in 2017 are the survivors of the same cohort in 2016. The estimated recruitment in 2017 is the mean of 2013-2015 recruitments. It can be seen a general increasing trend in the total number of matures, especially in 2013, due probably to the decreasing in the age of maturity. Since then it has decreased slightly. The maximum since 2005 in all the ages corresponding to the 2010 cohort (reaching 7 years old in 2017), followed by the 2011 cohort (reaching 6 years old in 2017). Since those cohorts, all the numbers at age have decreased (ages 1 to 5).

Figure 20 depicts the prior and posterior distributions of survivors at age at the end of the final assessment year, where by survivors(2016, a) it is meant individuals of age a + 1 at the beginning of 2017 (in other words, survivors(2016, a) = N(2017, 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 substantial updating of the prior distribution for survivors in almost all ages.

Figure 21 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 in 1996, between 2002 and 2005 and in years 2008 and 2010.

In Figure 22 the priors and posteriors for the total catch in 2011 and 2012 are shown. In both cases, although there is a small update of the total catch, with a posterior value a little greater than the prior value, the update is no important. While the median of the priors is 12 836 tons (exp(9.46)), the posterior medians are 13 600 tons for 2011 and 13 230 tons for 2012. Although with small updates, the values of the median of these catches since 2012 is essentially the same.

Figure 23 shows the prior and the posterior for 2016 of the natural mortality, M. In this case the posterior indicates that an M of value 0.2 is overestimated, as the posterior median is 0.19. This means a increase from the median estimated in the last approved assessment (0.16).

Bubble plot of standardised residuals (observed minus fitted values divided by estimated standard deviations and in logarithmic scale) for the survey abundance at age indices is displayed in Figure 24 for the Canadian survey and for the EU survey and by age for better understanding the patterns in Figures 25 and 26. 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.

For the Canadian survey, an absolute value near 2 is the age 7 of year 1985, so it could be seen that there are a few of values higher than 2 in absolute value. For years 1978-1981 all the ages higher than 3 have positive values while year 1982 has all its residuals except for age 1 negative or near 0, suggesting year effects (i.e. survey catchabilities that are below average in 1982 and above average in 1978-1981).

For the EU survey an absolute value near to 2 is age 2 of year 2005. In the case of this survey almost all residuals are below 2 in absolute value, and all the residuals above 2 in absolute value happened before 2005 except age 6 in 2015 and age 1 in 2016. In 1988 all residuals are negative except for the one for age 7, whereas the opposite happens in 1996, 1997 and 2011, suggesting year effects (i.e. survey catchabilities that are below average in 1988 and above average in 1996, 1997 and 2011). In 2012 all the standardized residuals except age 3 are positive. In 2014 and 2015 all are positive except age 1 and 2. For age 1 all the standardized residual are negative since 2014, being in 2016 the largest standardized residual for age 1 in the entire series. Positive residuals for ages 5-8+ can be observed in last years.

Biological Referent Points

Figure 27 shows a SSB-Recruitment plot and Figure 28 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 2014.

F_{lim} (0.139) for this stock is $F_{30\%SPR}$ calculated with the entire historic series (1972-2016). Figure 29 shows the Bayesian Yield per Recruit calculated with the data of years 1972-2016 as well as the value of F_{lim} and $F_{statusquo}$ (as the mean fishing mortality over 2012-2014).

Recruits per Spawner

Figure 30 displays the Recruits per Spawner. The variability over the years of the assessment is very high. Since 2007 a decreasing trend can be seen, reaching since 2013 a very low value.

Retrospective pattern

A retrospective analysis of five years was made (Figure 31). No evident patterns can be seen.

Projections

A new method to estimate the risk in the projections, that changes the way the number of individuals in the projected years are calculated, was approved by the Scientific Council. The new method solves some issues raised by the Fisheries Commission about the projections of the 3M cod by projecting a catch value instead of a distribution of catches. To see more details about the new projection method, see Fernández *et al.*, 2017. Stochastic projections of the stock dynamics from 2017 to 2019 have been conducted. The variability in the input data is taken from the results of the Bayesian assessment. Input data for the projections are as follows:

Numbers aged 2 to 8+ in 2017: estimated from the assessment.

Recruitments for 2017-2019: Recruits per spawner were drawn randomly from 2013-2015. The 2016 value was omitted due to uncertainty in estimating the recruitment.

Maturity ogive for 2017-2019: 2016 maturity ogive.

Natural mortality for 2017-2019: 2016 natural mortality from the assessment results.

Weight-at-age in stock and weight-at-age in catch for 2017-2019: 2016 weight-at-age.

PR at age for 2017-2018: Mean of the last three years (2014-2016) PRs.

F_{bar}(ages 3-5): Four scenarios were considered:

(*Scenario 1*) F_{bar}=F_{lim} (median value = 0.139).
(*Scenario 2*) F_{bar}=3/4F_{lim} (median value = 0.104).
(*Scenario 3*) F_{bar}=$F_{statusquo}$ (median value = 0.241).
(*Scenario 4*) F_{bar}=3/4$F_{statusquo}$ (median value = 0.180).

All scenarios assumed that the Yield for 2017 is the established TAC (13 931 t). $F_{statusquo}$ was established as the mean fishing mortality over 2014-2016.

Results for the four options are presented in Tables 11-18 and Figure 32. They indicate that under all scenarios total biomass during the projected years will decrease. In the case of the status quo scenario, the SSB is projected to decrease steadily until 2019 to a value close to B_{lim} (the probability of being below B_{lim} is 43%). The other scenarios show less decrease, or at best, stability. In all the cases the probability of being below B_{lim} at the beginning of 2019 is higher than 21%. Total numbers and numbers of mature will decrease in all the scenarios.

A clear trend in the biological parameters of this stock in recent years has led to revisions in estimate numbers from one year assessment to the actual ones in the next assessment. For this, only one-year projection is given.

Under all scenarios the probability of F exceeding F_{lim} is at least 35%.

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Table 1.- Total commercial cod catch in Division 3M. Reported nominal catches since 1960 and estimated total catch from 1988 to 2016 in tons.

Year	Estimated[2]	Portugal	Russia	Spain	France	Faroes	UK	Poland	Norway	Germany	Cuba	Others	Total[1]
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	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				458	34150
1969		7276	283	2681	11831					20		52	22143
1970		9847	494	1324	6239		3	53				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		24	76	29710
1980		3615	1056	706	301	3248		33	1080	355	1	62	10457
1981		3727	927	4100	79	3874			1154			12	13873
1982		3316	1262	4513	119	3121	33		375			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						269	10632
1988	28899	421	39	141		1100					3	14	1718
1989	48373	170	10	378								359	917
1990	40827	551	22	87		1262						840	2762
1991	16229	2838	1	1416		2472	26		897		5	1334	8989
1992	25089	2201	1	4215		747	5				6	51	7226
1993	15958	3132	0	2249		2931						4	8316
1994	29916	2590	0	1952		2249			1			93	6885
1995	10372	1641	0	564		1016						0	3221
1996	2601	1284	0	176		700	129			16		0	2305
1997	2933	1433	0	1			23					0	1457
1998	705	456	0									0	456
1999	353	2	0									0	2
2000	55	30	6									0	36
2001	37	56	0									0	56
2002	33	32	1									0	33
2003	16	7	0									9	16
2004	5	18	2									3	23
2005	19	16	0			7						3	26
2006	339	51	1	16								55	123
2007	345	58	6	33								28	125
2008	889	219	74	42	3	0						63	401
2009	1161	856	87	85		22						122	1172
2010	9291	1345	374	921		1183	761		514			147	5245
2011	13600	2412	655	1610	200	2211	1063		1301		185	340	9977
2012	13230	2593	745	1597	131	2045	868		809		172	108	9068

2013	13985	4427	896	2380		2723	1328		1322			445	13521
2014	14290	5345	950	2099		3370		393	1344			855	14356
2015	13785	4680	893	1999		3319			1296			641	12828
2016	14023	5958	893	1232		3124	1198		1318			72	13795

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

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

	1	2	3	4	5	6	7	8+
1972	0	0	278	19303	12372	6555	3083	3177
1973	0	0	2035	116	11709	3470	853	1085
1974	0	0	5999	11130	2232	1894	271	257
1975	0	0	7090	2436	1241	238	281	258
1976	0	0	17564	10653	386	100	63	5
1977	0	0	119	17581	8502	436	267	318
1978	0	0	428	3092	18077	3615	329	270
1979	0	0	167	2616	5599	5882	316	137
1980	0	0	551	500	1423	1051	1318	96
1981	0	0	1732	6768	161	326	189	539
1982	0	0	21	3040	1926	310	97	357
1983	0	0	2818	713	765	657	94	131
1984	0	0	9	2229	966	59	90	146
1985	0	0	19	5499	3549	1232	931	218
1986	0	2549	2266	4251	2943	1061	169	162
1987	814	1848	3102	1915	1259	846	313	112
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
2011[1]	0.003	0.098	0.293	0.126	0.198	0.161	0.063	0.056
2012[1]	0.008	0.080	0.297	0.171	0.199	0.136	0.061	0.048
2013	31	894	5624	1236	1158	640	382	252
2014	8	15	809	4554	1581	871	509	341
2015	0	94	402	1548	1457	2596	602	480
2016		40	884	733	1845	1176	894	712

[1] As there is no total catch available, the proportion of number per age is given

Table 3.- Weight-at-age (kg) in catch. In red, the filled cero values.

	1	2	3	4	5	6	7	8+
1972	0.091	0.165	0.811	0.722	0.981	1.500	1.930	2.296
1973	0.091	0.165	0.633	0.314	1.300	0.994	0.828	3.430
1974	0.091	0.165	0.657	0.805	1.769	2.829	3.983	7.701
1975	0.091	0.165	0.697	1.636	1.798	2.658	3.766	6.497
1976	0.091	0.165	0.671	1.293	4.192	5.085	5.923	6.298
1977	0.091	0.165	0.314	0.845	1.400	3.433	5.156	7.722
1978	0.091	0.165	0.374	0.600	1.102	1.582	2.658	6.351
1979	0.091	0.165	0.790	1.070	1.480	2.450	4.350	7.079
1980	0.091	0.165	0.859	1.137	1.747	2.466	3.167	4.676
1981	0.091	0.165	0.620	1.250	1.880	2.680	3.190	4.747
1982	0.091	0.165	0.760	1.340	2.450	2.870	4.680	6.146
1983	0.091	0.165	1.330	1.140	2.240	3.530	4.760	9.163
1984	0.091	0.165	0.460	1.866	3.695	3.660	6.588	6.655
1985	0.091	0.165	0.283	0.851	1.605	2.816	4.522	7.978
1986	0.091	0.165	0.411	0.784	1.631	2.836	4.317	7.389
1987	0.091	0.133	0.327	1.040	1.890	2.993	4.440	7.630
1988	0.058	0.198	0.442	0.821	2.190	3.386	5.274	7.969
1989	0.069	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	0.116	0.298	0.414	0.592	1.093	1.704	2.619	3.865
1993	0.114	0.210	0.509	0.894	1.829	2.233	3.367	4.841
1994	0.113	0.289	0.497	0.792	1.916	2.719	2.158	4.239
1995	0.111	0.288	0.415	0.790	1.447	2.266	3.960	5.500
1996	0.109	0.286	0.789	1.051	1.543	2.429	2.650	4.954
1997	0.107	0.360	0.402	0.640	0.869	1.197	1.339	4.408
1998	0.106	0.435	0.719	1.024	1.468	1.800	2.252	3.862
1999	0.104	0.509	0.920	1.298	1.848	2.436	3.513	4.893
2000	0.102	0.583	0.672	1.749	2.054	2.836	3.618	5.055
2001	0.100	0.481	0.998	1.696	2.560	3.303	3.905	5.217
2002	0.099	0.588	1.323	1.388	2.572	3.770	5.158	5.603
2003	0.097	0.462	1.063	1.455	2.978	3.696	5.859	6.120
2004	0.095	0.839	1.677	2.009	3.353	5.576	6.241	8.273
2005	0.093	0.895	1.618	2.368	3.259	4.767	6.177	6.553
2006	0.092	1.081	1.462	2.283	3.966	5.035	6.332	7.997
2007	0.090	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	4.810	5.900	9.534
2010	0.162	0.700	1.279	1.829	2.764	4.372	4.199	8.575
2011	0.086	0.396	0.939	1.523	2.224	3.558	5.979	8.677
2012	0.086	0.374	0.990	1.491	2.135	3.585	6.198	9.041
2013	0.067	0.284	0.758	1.289	2.027	2.868	4.476	8.243
2014	0.108	0.203	0.538	1.108	1.809	2.874	4.087	7.669
2015	0.085	0.261	0.531	0.857	1.370	1.938	3.570	6.252
2016	0.085	0.191	0.550	0.787	1.238	2.150	3.405	6.948

Table 4- Canadian bottom trawl survey abundance at age and total (thousands) and total biomass (tons).

	1	2	3	4	5	6	7	8+	Total Abundance	Total Biomass
1978	0	95	4757	15531	45688	12135	476	570	79252	85413
1979	0	4675	1067	5619	5465	6676	1706	405	25613	42523
1980	0	1030	19475	2377	2990	2737	3912	224	32745	45107
1981	32	0	5172	15479	975	2108	1041	2211	27018	43862
1982	627	1781	21	1663	978	32	150	377	5629	8140
1983	293	71000	7817	319	2357	958	45	401	83190	37524
1984	43	1527	15834	1897	74	646	427	221	20669	18063
1985	39	520	6212	19955	774	50	105	196	27851	22233

Table 5.- EU bottom trawl survey abundance at age and total (thousands) and total biomass (tons).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total Abundance	Total Biomass
1988	4850	78920	49050	13370	1450	210	220	60	0	0	0	0	0	0	148130	40839
1989	22100	12100	106400	63400	23800	1600	200	100	0	0	0	0	0	0	229700	114050
1990	2660	14020	5920	19970	18420	5090	390	170	90	30	0	0	0	0	66760	59362
1991	146100	29400	20600	2500	7800	2100	300	100	0	0	0	0	0	0	208900	40248
1992	75480	44280	6290	2540	410	1500	270	10	0	0	10	0	0	0	130790	26719
1993	4600	156100	35400	1300	1500	200	600	100	0	0	0	0	0	0	199800	60963
1994	3340	4550	31580	5760	150	70	10	120	0	10	0	0	0	0	45590	26463
1995	1640	13670	1540	4490	1070	40	30	0	20	10	0	0	0	0	22510	9695
1996	41	3580	7649	1020	2766	221	9	6	0	0	0	0	0	0	15292	9013
1997	42	171	3931	5430	442	1078	24	0	0	0	0	6	0	0	11124	9966
1998	27	94	106	1408	1763	87	165	0	6	0	0	0	0	0	3656	4986
1999	7	96	128	129	792	491	21	7	0	0	0	0	0	0	1671	2854
2000	186	16	343	207	100	467	180	11	17	0	0	5	0	5	1537	3062
2001	487	2048	15	125	81	15	146	101	6	6	6	0	0	0	3036	2695
2002	0	1340	609	24	68	36	28	96	33	0	6	0	0	0	2240	2496
2003	665	53	610	131	22	47	7	8	37	25	0	0	0	0	1605	1593
2004	0	3379	25	602	168	5	10	3	5	16	0	0	0	0	4213	4071
2005	8069	16	1118	78	708	136		17	8	8	0	0	0	0	10158	5242
2006	19710	3883	62	1481	86	592	115	7	0	7	14	0	7	0	25964	12505
2007	3910	11620	5020	21	1138	58	425	74	13	20	0	0	0	0	22299	23886
2008	6090	16670	12440	4530	70	940	60	230	80	0	10	0	0	0	41120	43676
2009	5139	7479	16150	14310	4154	26	1091	0	335	0	0	14	0	0	48698	75228
2010	66370	27689	8654	7633	4911	1780	8	442	46	251	26	0	0	0	117810	69295
2011	347674	142999	16993	6309	7739	3089	1191	0	215	0	89	0	0	0	526298	106151
2012	103494	128087	10942	11721	4967	4781	1630	832	24	93	30	101	0	17	266719	113227
2013	5525	67521	32339	4776	4185	2782	1807	963	278	40	29	32	5	0	120282	72289
2014	7282	2372	48564	43168	17861	6842	3447	1931	1551	600	79	54	8	0	133759	159939
2015	1141	12952	7250	25614	14107	21854	3434	1426	762	366	194	14	21	28	89163	114807
2016	56	4485	14356	2230	14540	12375	4814	1157	522	303	145	28	20	0	55031	80583

Table 6.- Weight-at-age (kg) in stock. In red, the filled cero values.

	1	2	3	4	5	6	7	8+
1972	0.05	0.20	0.81	0.72	0.98	1.50	1.93	2.30
1973	0.05	0.20	0.63	0.31	1.30	0.99	0.83	3.43
1974	0.05	0.20	0.66	0.81	1.77	2.83	3.98	7.70
1975	0.05	0.20	0.70	1.64	1.80	2.66	3.77	6.50
1976	0.05	0.20	0.67	1.29	4.19	5.09	5.92	6.30
1977	0.05	0.20	0.31	0.85	1.40	3.43	5.16	7.72
1978	0.05	0.20	0.37	0.60	1.10	1.58	2.66	6.35
1979	0.05	0.20	0.79	1.07	1.48	2.45	4.35	7.08
1980	0.05	0.20	0.86	1.14	1.75	2.47	3.17	4.68
1981	0.05	0.20	0.62	1.25	1.88	2.68	3.19	4.75
1982	0.05	0.20	0.76	1.34	2.45	2.87	4.68	6.15
1983	0.05	0.20	1.33	1.14	2.24	3.53	4.76	9.16
1984	0.05	0.20	0.46	1.87	3.70	3.66	6.59	6.66
1985	0.05	0.20	0.28	0.85	1.61	2.82	4.52	7.98
1986	0.05	0.20	0.41	0.78	1.63	2.84	4.32	7.39
1987	0.05	0.20	0.33	1.04	1.89	2.99	4.44	7.63
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	0.60	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	5.82	6.21
2006	0.09	0.70	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
2011	0.04	0.23	0.97	1.70	2.45	3.74	6.26	9.67
2012	0.07	0.37	0.73	1.35	1.99	2.66	4.93	7.81
2013	0.07	0.17	0.69	1.16	2.00	2.75	4.21	7.61
2014	0.05	0.17	0.35	1.06	1.62	2.54	3.85	8.44
2015	0.05	0.16	0.47	0.75	1.22	1.85	3.43	6.77
2016	0.04	0.17	0.41	0.78	1.30	2.02	2.88	6.91

Table 7.- Maturity at age and age of first maturation (median values of ogives).

	1	2	3	4	5	6	7	8+	a50
1972	0.000	0.000	0.000	0.002	0.507	0.998	1.000	1.000	5.00
1973	0.000	0.000	0.000	0.002	0.507	0.998	1.000	1.000	5.00
1974	0.000	0.000	0.000	0.002	0.507	0.998	1.000	1.000	5.00
1975	0.000	0.000	0.000	0.002	0.507	0.998	1.000	1.000	5.00
1976	0.000	0.000	0.000	0.002	0.507	0.998	1.000	1.000	5.00
1977	0.000	0.000	0.000	0.002	0.507	0.998	1.000	1.000	5.00
1978	0.000	0.000	0.000	0.002	0.507	0.998	1.000	1.000	5.00
1979	0.000	0.000	0.000	0.008	0.154	0.813	0.991	1.000	5.54
1980	0.000	0.000	0.002	0.029	0.302	0.862	0.989	1.000	5.31
1981	0.000	0.000	0.005	0.104	0.716	0.982	0.999	1.000	4.70
1982	0.000	0.000	0.007	0.146	0.809	0.991	1.000	1.000	4.55
1983	0.000	0.000	0.007	0.146	0.809	0.991	1.000	1.000	4.55
1984	0.000	0.000	0.007	0.146	0.809	0.991	1.000	1.000	4.55
1985	0.000	0.000	0.007	0.146	0.809	0.991	1.000	1.000	4.55
1986	0.000	0.000	0.007	0.146	0.809	0.991	1.000	1.000	4.55
1987	0.000	0.000	0.007	0.146	0.809	0.991	1.000	1.000	4.55
1988	0.054	0.099	0.175	0.291	0.441	0.603	0.745	0.879	5.36
1989	0.054	0.099	0.175	0.291	0.441	0.603	0.745	0.879	5.36
1990	0.054	0.099	0.175	0.291	0.441	0.603	0.745	0.879	5.36
1991	0.018	0.045	0.111	0.247	0.463	0.687	0.849	0.951	5.16
1992	0.002	0.011	0.048	0.184	0.503	0.819	0.953	0.993	4.99
1993	0.001	0.007	0.049	0.282	0.751	0.959	0.994	1.000	4.46
1994	0.000	0.001	0.050	0.657	0.986	1.000	1.000	1.000	3.82
1995	0.000	0.000	0.006	0.803	1.000	1.000	1.000	1.000	3.79
1996	0.000	0.000	0.029	0.666	0.993	1.000	1.000	1.000	3.84
1997	0.000	0.008	0.111	0.670	0.971	0.998	1.000	1.000	3.75
1998	0.000	0.002	0.096	0.874	0.998	1.000	1.000	1.000	3.54
1999	0.000	0.001	0.130	0.902	0.999	1.000	1.000	1.000	3.46
2000	0.000	0.001	0.160	0.971	1.000	1.000	1.000	1.000	3.34
2001	0.000	0.001	0.315	0.998	1.000	1.000	1.000	1.000	3.12
2002	0.000	0.010	0.636	0.997	1.000	1.000	1.000	1.000	2.89
2003	0.001	0.024	0.513	0.978	0.999	1.000	1.000	1.000	2.99
2004	0.000	0.000	0.100	0.967	1.000	1.000	1.000	1.000	3.40
2005	0.041	0.171	0.502	0.830	0.959	0.991	0.998	1.000	3.00
2006	0.000	0.014	0.365	0.959	0.999	1.000	1.000	1.000	3.15
2007	0.000	0.012	0.261	0.920	0.997	1.000	1.000	1.000	3.31
2008	0.000	0.012	0.231	0.882	0.995	1.000	1.000	1.000	3.37
2009	0.000	0.010	0.181	0.830	0.991	1.000	1.000	1.000	3.49
2010	0.000	0.009	0.167	0.812	0.989	1.000	1.000	1.000	3.52
2011	0.001	0.008	0.072	0.428	0.878	0.986	0.999	1.000	4.13
2012	0.000	0.000	0.018	0.578	0.990	1.000	1.000	1.000	3.93
2013	0.004	0.037	0.285	0.804	0.977	0.998	1.000	1.000	3.39
2014	0.000	0.003	0.046	0.400	0.902	0.992	0.999	1.000	4.15
2015	0.000	0.000	0.004	0.117	0.794	0.991	1.000	1.000	4.60
2016	0.000	0.000	0.004	0.047	0.393	0.894	0.991	1.000	5.17

Table 8.- 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%**
1972	85500	80125	93443	37364	34084	41138	18230	14780	24303	0.691	0.643	0.727
1973	50863	46944	56907	20600	17301	24336	64335	50170	89251	0.589	0.538	0.619
1974	54951	49171	64560	15355	13410	20062	127300	99729	176910	1.357	1.174	1.482
1975	71074	62081	85778	7890	6351	11984	24050	18200	34762	0.668	0.549	0.757
1976	114594	102394	133951	8997	6860	13091	10500	8165	14571	0.337	0.296	0.371
1977	86525	78950	98394	21494	17418	28031	3165	2342	4720	0.462	0.424	0.493
1978	57996	53694	64467	29177	24070	35097	20915	16420	28730	0.469	0.424	0.501
1979	51219	46513	58231	24746	21617	29587	14110	10920	19901	0.714	0.641	0.773
1980	32254	28665	38201	11867	9990	16023	8090	5930	12140	0.557	0.499	0.602
1981	35132	30355	42442	13497	9714	19644	21720	16780	30661	0.501	0.456	0.537
1982	31245	27932	36460	13505	11920	15982	21440	16460	30181	0.600	0.540	0.647
1983	41990	36995	49757	12535	10774	15160	13460	10430	18831	0.274	0.236	0.306
1984	47616	42815	54847	20138	17588	23536	15170	11670	21351	0.235	0.211	0.254
1985	39772	36511	44810	21179	19423	23445	60285	47200	83230	0.578	0.516	0.620
1986	42427	37607	50058	15846	14084	18599	122700	98920	163305	0.750	0.676	0.808
1987	56079	49288	66677	12765	11288	15596	77110	62649	101600	0.442	0.389	0.483
1988	67175	61256	76078	19651	15632	24899	16300	12810	22310	0.501	0.452	0.541
1989	108196	100429	119586	34403	27973	42271	21400	17450	27980	0.852	0.785	0.901
1990	65920	61522	72240	25789	21979	30152	26790	22250	34190	0.882	0.813	0.937
1991	45425	41690	51117	17916	15207	21463	67035	56960	83140	0.486	0.446	0.517
1992	59669	55806	65336	21133	18586	24037	60935	51219	76320	1.522	1.431	1.592
1993	47290	43751	52602	10456	8903	12747	3258	2759	4137	1.003	0.919	1.069
1994	50629	47100	56172	21795	18898	26373	4638	3403	7273	0.935	0.878	0.980
1995	22968	21573	25167	19598	18326	21391	2366	1893	3291	1.391	1.242	1.498
1996	5873	5182	7056	3513	3098	4167	147	92	253	0.670	0.553	0.762
1997	4834	4114	6131	3225	2670	4210	143	89	244	0.739	0.577	0.898
1998	3339	2454	4918	3122	2260	4691	220	149	352	0.312	0.217	0.433
1999	2426	1607	3869	2271	1467	3695	37	26	58	0.296	0.212	0.403
2000	2164	1302	3711	1993	1144	3542	364	208	641	0.182	0.121	0.266
2001	1807	1245	2659	1596	1036	2419	592	361	1036	0.035	0.024	0.052
2002	2101	1551	2900	1781	1251	2562	73	43	128	0.015	0.007	0.035
2003	2316	1789	3036	2034	1537	2747	1264	799	2145	0.012	0.007	0.019
2004	3762	3047	4666	3009	2369	3859	90	63	140	0.003	0.002	0.005
2005	4175	3468	5061	3394	2795	4106	3990	2641	6732	0.007	0.004	0.011
2006	6964	5556	9167	3788	3011	4813	8154	5649	13222	0.211	0.159	0.270
2007	12984	10316	17279	5326	4101	7062	11040	7982	17110	0.031	0.023	0.042
2008	20567	16568	26935	9778	7840	12744	10710	7882	16421	0.074	0.056	0.096
2009	31102	25856	39233	18596	15288	23495	14100	10390	21500	0.044	0.035	0.054
2010	46295	39664	56033	31712	26784	38294	21570	15890	32901	0.263	0.216	0.311
2011	50858	42702	62280	30688	25037	38558	33835	24178	54141	0.287	0.212	0.371
2012	54404	44664	69739	27756	21754	37783	26595	15880	47773	0.233	0.173	0.300
2013	54829	45689	69036	36577	30133	46685	4882	3072	8171	0.273	0.214	0.327
2014	50512	41846	63856	32929	27275	41701	11190	6194	20861	0.259	0.191	0.345
2015	42936	33754	56655	27893	21812	38779	4854	2211	10761	0.182	0.126	0.269
2016	42047	31284	58187	26698	19081	40024	2475	831	8178	0.276	0.187	0.421
2017[1]	36314	23245	55649	27187	15371	45374	3399	936	8693			

[1] Estimated results at the beginning of the year

Table 9.- F at age (posterior median).

	F at age							
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8+**
1972	0.000	0.000	0.063	0.738	1.276	1.877	3.276	3.276
1973	0.000	0.000	0.117	0.034	1.617	2.124	2.102	2.102
1974	0.000	0.000	0.752	1.745	1.608	1.587	1.192	1.192
1975	0.000	0.000	0.195	0.799	1.025	0.727	1.205	1.205
1976	0.000	0.000	0.250	0.494	0.267	0.193	0.419	0.419
1977	0.000	0.000	0.008	0.421	0.957	0.546	1.174	1.174
1978	0.000	0.000	0.068	0.290	1.051	1.746	1.091	1.091
1979	0.000	0.000	0.088	0.728	1.327	1.335	0.695	0.695
1980	0.000	0.000	0.043	0.408	1.222	0.995	1.436	1.436
1981	0.000	0.000	0.219	1.065	0.219	1.100	0.465	0.465
1982	0.000	0.000	0.004	0.736	1.063	0.846	1.289	1.289
1983	0.000	0.000	0.234	0.188	0.402	1.542	0.672	0.672
1984	0.000	0.000	0.001	0.290	0.416	0.047	0.943	0.943
1985	0.000	0.000	0.002	0.688	1.047	1.618	2.682	2.682
1986	0.000	0.058	0.275	0.953	1.028	1.118	1.122	1.122
1987	0.012	0.020	0.091	0.391	0.847	0.989	1.335	1.335
1988	0.000	0.063	0.418	0.539	0.550	0.762	1.445	1.445
1989	0.000	0.004	0.423	0.840	1.293	0.919	1.337	1.337
1990	0.000	0.016	0.243	1.053	1.351	1.532	1.325	1.325
1991	0.000	0.028	0.504	0.355	0.600	0.778	1.237	1.237
1992	0.000	0.367	0.986	1.349	2.235	1.548	2.776	2.776
1993	0.000	0.060	0.698	1.231	1.084	1.881	1.470	1.470
1994	0.000	0.687	1.238	1.184	0.385	0.639	0.404	0.404
1995	0.000	0.000	0.299	1.448	2.440	3.216	1.573	1.573
1996	0.000	0.046	0.286	0.692	1.038	0.522	0.000	0.000
1997	0.000	0.000	0.854	0.556	0.810	0.889	0.604	0.604
1998	0.000	0.000	0.092	0.419	0.413	0.380	0.123	0.123
1999	0.000	0.000	0.184	0.245	0.438	0.139	0.057	0.057
2000	0.000	0.449	0.503	0.016	0.023	0.028	0.003	0.003
2001	0.000	0.033	0.000	0.061	0.041	0.000	0.017	0.017
2002	0.000	0.006	0.017	0.010	0.012	0.005	0.016	0.016
2003	0.000	0.005	0.010	0.011	0.010	0.005	0.005	0.005
2004	0.000	0.001	0.005	0.002	0.002	0.004	0.001	0.001
2005	0.000	0.005	0.005	0.009	0.006	0.004	0.003	0.003
2006	0.000	0.007	0.419	0.134	0.072	0.053	0.018	0.018
2007	0.000	0.000	0.012	0.021	0.060	0.055	0.092	0.092
2008	0.000	0.011	0.027	0.069	0.124	0.117	0.072	0.072
2009	0.000	0.003	0.007	0.053	0.073	0.000	0.126	0.126
2010	0.002	0.044	0.189	0.314	0.292	0.401	0.301	0.301
2011	0.001	0.036	0.227	0.178	0.457	0.742	0.885	0.885
2012	0.002	0.016	0.122	0.170	0.407	0.584	0.678	0.678
2013	0.007	0.046	0.318	0.141	0.363	0.471	0.663	0.663
2014	0.001	0.004	0.053	0.458	0.268	0.513	0.870	0.870
2015	0.000	0.011	0.145	0.134	0.255	0.952	0.824	0.824
2016	0.000	0.011	0.138	0.423	0.230	0.334	1.088	1.088

Table 10.- N at age (posterior median), with the total number and number of matures (posterior median) by year.

	N at age									
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8+**	**Total**	**Matures**
1972	18230	24400	4986	40670	18880	8534	3538	3471	122709	25504
1973	64335	15080	20210	3866	16070	4350	1072	1318	126301	15081
1974	127300	53255	12480	14850	3078	2628	428	397	214416	5236
1975	24050	105300	44085	4871	2137	508	442	398	181791	2584
1976	10500	19910	87210	30030	1810	628	202	16	150306	2002
1977	3165	8685	16460	56280	15170	1143	427	498	101828	10206
1978	20915	2623	7192	13520	30570	4819	545	440	80624	21477
1979	14110	17310	2170	5563	8380	8806	694	297	57330	9558
1980	8090	11680	14320	1641	2222	1833	1904	135	41825	4417
1981	21720	6694	9664	11350	902	540	560	1581	53011	4615
1982	21440	17970	5543	6418	3239	598	147	530	55885	4924
1983	13460	17750	14880	4570	2544	922	211	291	54628	4304
1984	15170	11140	14690	9738	3126	1404	162	259	55689	5931
1985	60285	12550	9224	12150	6024	1698	1103	248	103282	9826
1986	122700	49915	10360	7611	5044	1741	276	259	197906	7658
1987	77110	101600	39000	6516	2424	1486	468	164	228768	5453
1988	16300	63095	82405	29455	3643	857	454	228	196437	32962
1989	21400	13480	49040	44930	14210	1732	329	300	145421	32162
1990	26790	17710	11110	26580	16060	3216	567	172	102205	22690
1991	67035	22170	14440	7215	7671	3439	571	115	122656	12430
1992	60935	55480	17840	7224	4188	3476	1301	532	150976	9776
1993	3258	50420	31810	5508	1549	370	609	297	93821	5933
1994	4638	2698	39325	13110	1329	432	46	597	62175	13111
1995	2366	3825	1122	9429	3318	748	188	314	21310	12186
1996	147	1959	3157	687	1829	238	25	1	8043	2666
1997	143	122	1549	1960	283	534	116	1	4708	2464
1998	220	118	101	545	928	104	181	19	2216	1764
1999	37	183	98	76	298	509	59	20	1280	1002
2000	364	30	150	68	49	159	364	1	1185	696
2001	592	301	16	75	55	39	128	128	1334	438
2002	73	492	241	13	58	44	32	208	1161	525
2003	1264	61	404	194	11	47	36	197	2214	706
2004	90	1045	50	330	158	9	39	190	1911	738
2005	3990	75	863	41	272	130	7	190	5568	1272
2006	8154	3304	61	711	33	223	106	20	12612	1154
2007	11040	6744	2706	33	513	26	174	58	21294	1691
2008	10710	9139	5582	2207	27	400	20	54	28139	3913
2009	14100	8859	7466	4493	1696	20	294	66	36994	7354
2010	21570	11660	7316	6124	3521	1296	16	436	51939	11742
2011	33835	17800	9228	5010	3688	2169	715	530	72975	9846
2012	26595	27910	14180	6048	3456	1906	842	766	81703	11058
2013	4882	21960	22730	10360	4199	1875	871	568	67445	23564
2014	11190	3996	17300	13650	7419	2397	965	637	57554	17394
2015	4854	9212	3278	13580	7142	4663	1183	929	44841	14482
2016	2475	3982	7544	2344	9848	4551	1483	1159	33386	11180
2017[1]	3399	2033	3260	5415	1265	6470	2692	737	25271	

[1] Estimated results at the beginning of the year

Table 11.- N-at-age in prediction years (medians) with $F_{bar}=F_{lim}=0.139$ including total number and number of matures.

Year/Age	1	2	3	4	5	6	7	8+	Total	Matures
2017	3399	2033	3260	5415	1265	6470	2692	737	25272	10543
2018	3159	2809	1653	2426	3426	836	3206	1426	18940	7233
2019	2063	2611	2290	1213	1550	2344	444	2282	14796	5904

Table 12.- Projections results (median and 90% CI) with $F_{bar}=F_{lim}=0.139$

Year	Total Biomass	SSB	P(SSB<B_{lim})	Yield
2017	36314 (23245 - 55649)	27187 (15371 - 45374)	3%	13931
2018	30508 (12993 - 57331)	23634 (7923 - 49139)	18%	10297
2019	27754 (4121 - 62281)	22913 (1799 - 55727)	27%	

Table 13.- N-at-age in prediction years (medians) with $F_{bar}=3/4F_{lim}=0.104$ including total number and number of matures.

Year/Age	1	2	3	4	5	6	7	8+	Total	Matures
2017	3399	2033	3260	5415	1265	6470	2692	737	25272	10543
2018	3159	2809	1653	2426	3426	836	3206	1426	18940	7233
2019	2063	2611	2299	1249	1656	2451	495	2629	15452	6430

Table 14.- Projections results (median and 90% CI) with $F_{bar}=3/4F_{lim}=0.104$

Year	Total Biomass	SSB	P(SSB<B_{lim})	Yield
2017	36314 (23245 - 55649)	27187 (15371 - 45374)	3%	13931
2018	30508 (12993 - 57331)	23634 (7923 - 49139)	18%	8182
2019	30703 (6907 - 65109)	25658 (3973 - 58324)	21%	

Table 15.- N-at-age in prediction years (medians) with $F_{bar}=F_{2014\text{-}2016}=0.241$ including total number and number of matures.

Year/Age	1	2	3	4	5	6	7	8+	Total	Matures
2017	3399	2033	3260	5415	1265	6470	2692	737	25272	10543
2018	3159	2809	1653	2426	3426	836	3206	1426	18940	7233
2019	2063	2611	2262	1099	1293	2060	326	1517	13229	4670

Table 16.- Projections results (median and 90% CI) with $F_{bar}=F_{2014\text{-}2016}=0.241$

Year	Total Biomass	SSB	P(SSB<B_{lim})	Yield
2017	36314 (23245 - 55649)	27187 (15371 - 45374)	3%	13931
2018	30508 (12993 - 57331)	23634 (7923 - 49139)	18%	15127
2019	21265 (1644 - 55804)	16653 (229 - 49345)	43%	

Table 17.- N-at-age in prediction years (medians) with $F_{bar}=3/4F_{2014\text{-}2016}=0.180$ including total number and number of matures.

Year/Age	1	2	3	4	5	6	7	8+	Total	Matures
2017	3399	2033	3260	5415	1265	6470	2692	737	25272	10543
2018	3159	2809	1653	2426	3426	836	3206	1426	18940	7233
2019	2063	2611	2279	1167	1438	2225	393	1935	14110	5352

Table 18.- Projections results (median and 90% CI) with $3/4F_{bar}=F_{2014\text{-}2016}=0.180$

Year	Total Biomass	SSB	P(SSB<B_{lim})	Yield
2017	36314 (23245 - 55649)	27187 (15371 - 45374)	3%	13931
2018	30508 (12993 - 57331)	23634 (7923 - 49139)	18%	12435
2019	24854 (2298 - 59365)	20105 (320 - 52774)	34%	

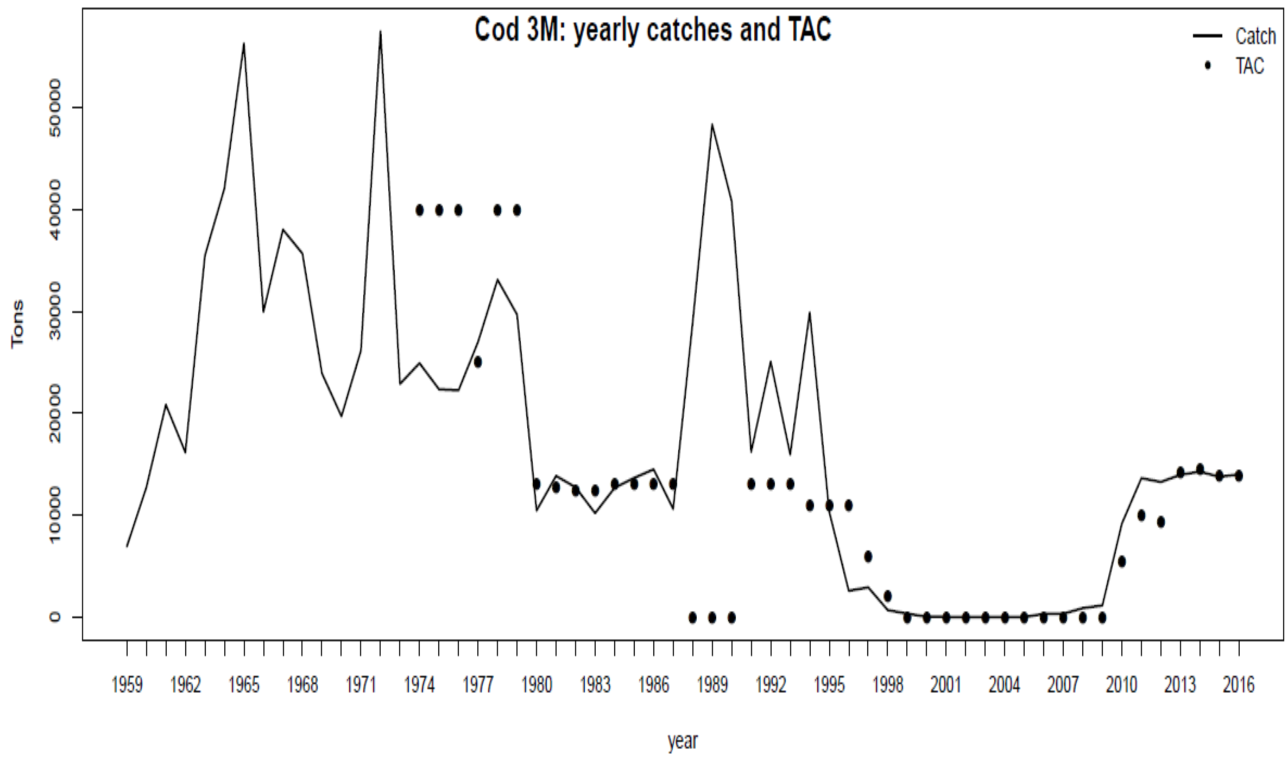


Fig. 1. Catch and TAC of the 3M cod for the period 1959-2016.

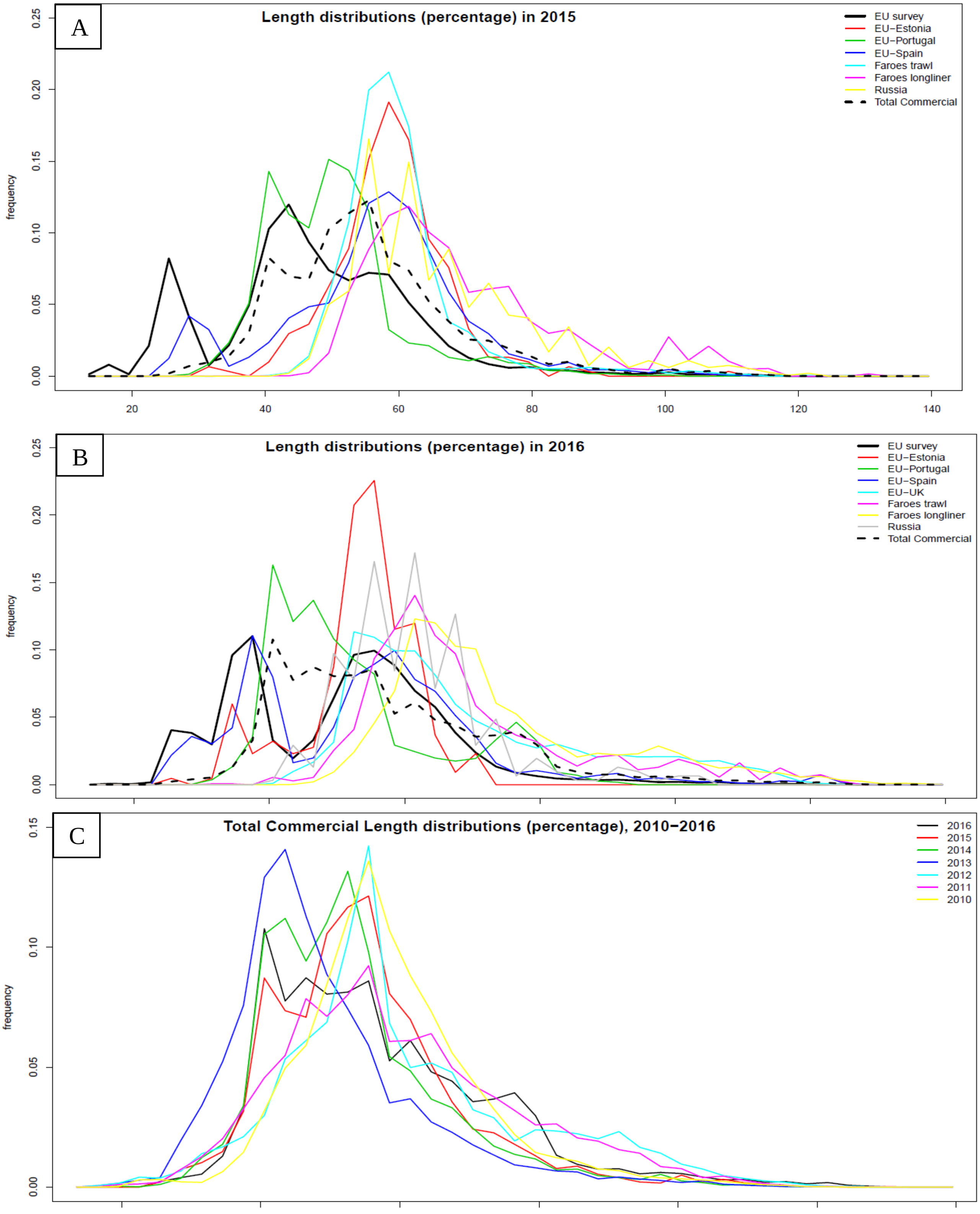


Fig. 2. Length frequencies in commercial catches and EU survey in 2015, 2016 and total commercial for the last fishery period (2010-2016).

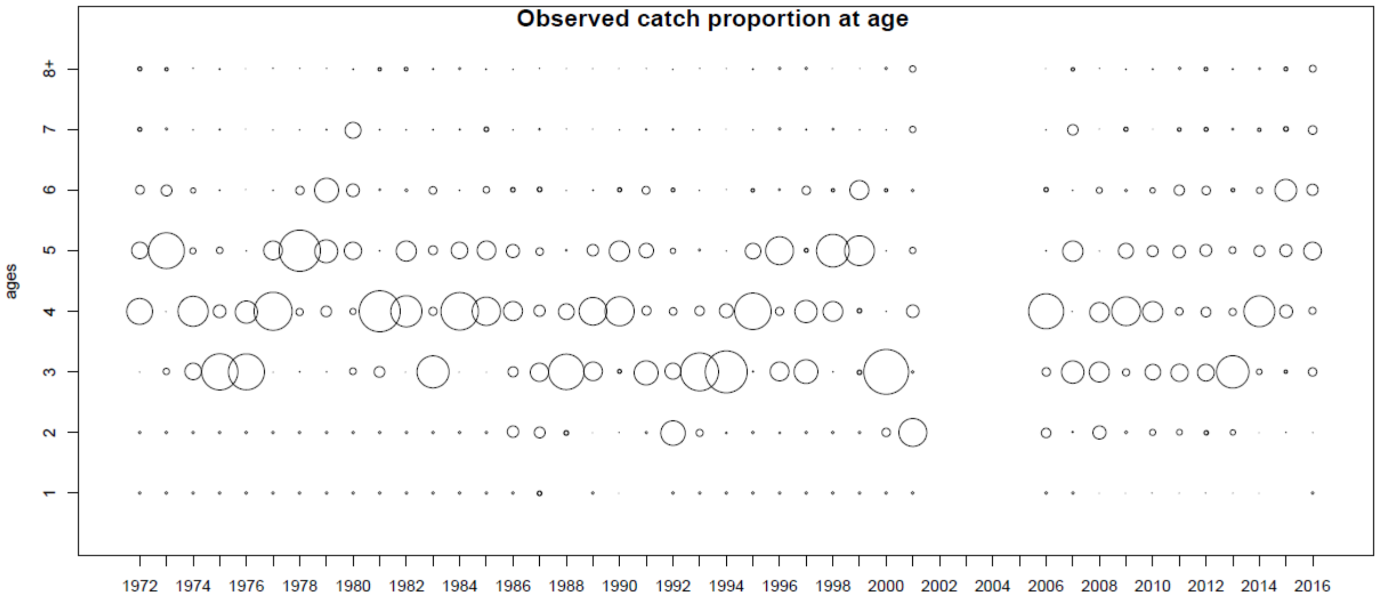


Fig. 3. Commercial catch proportions at age.

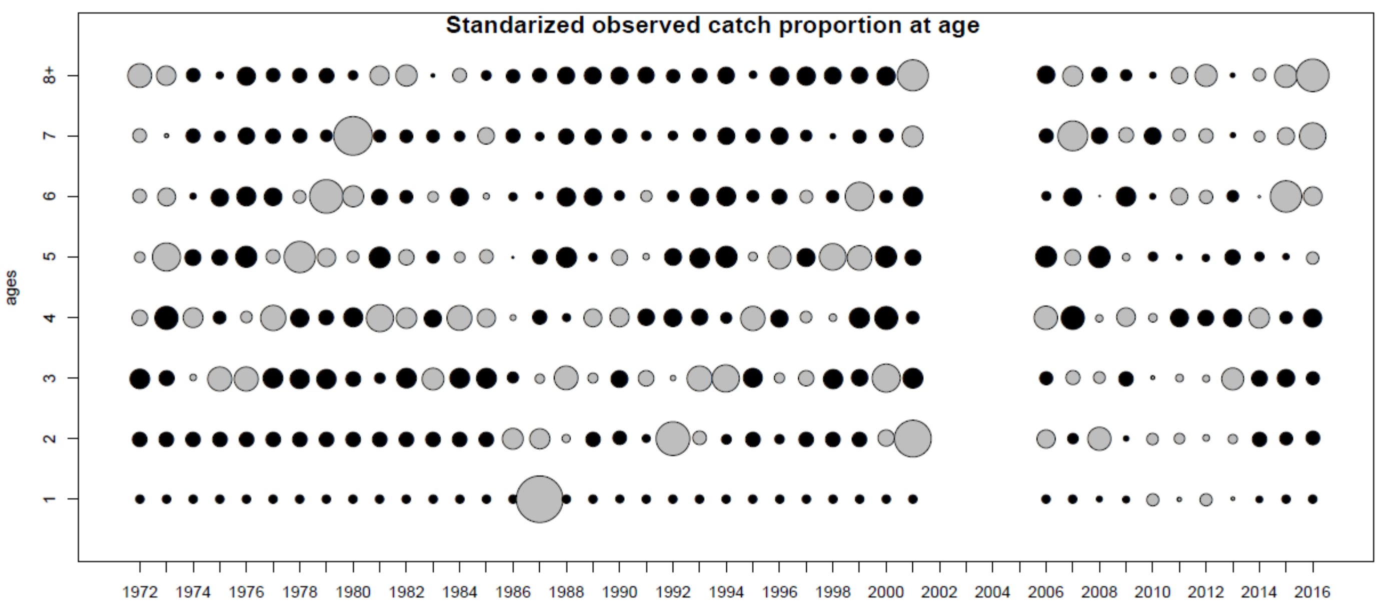


Fig. 4. Commercial catch standardised proportions at age. Grey and black values indicate values above and below the average. The larger the bubble size the larger the magnitude of the value.

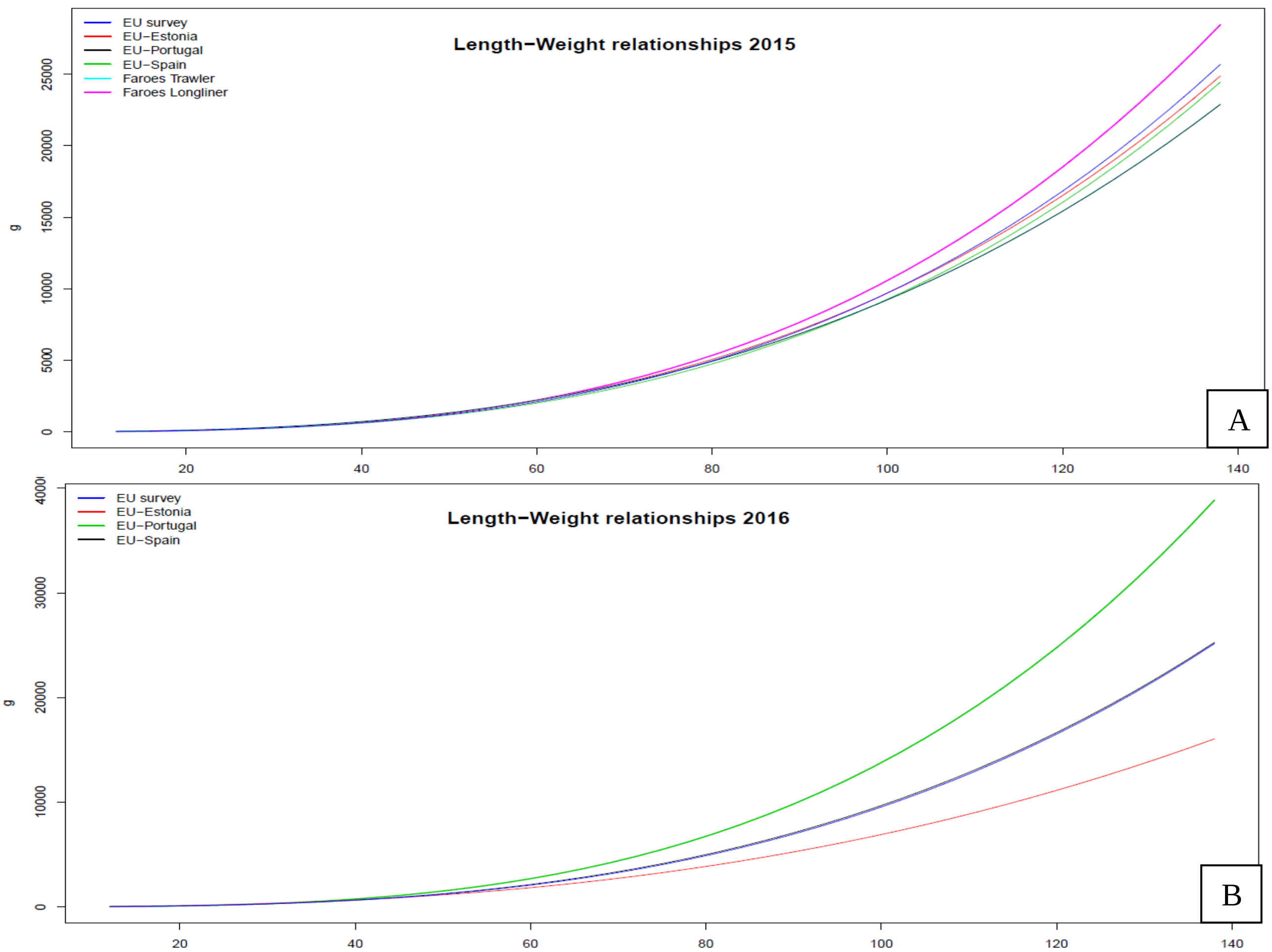


Fig.5. Length-weight relationships for commercial catches and EU survey in 2015 and 2016.

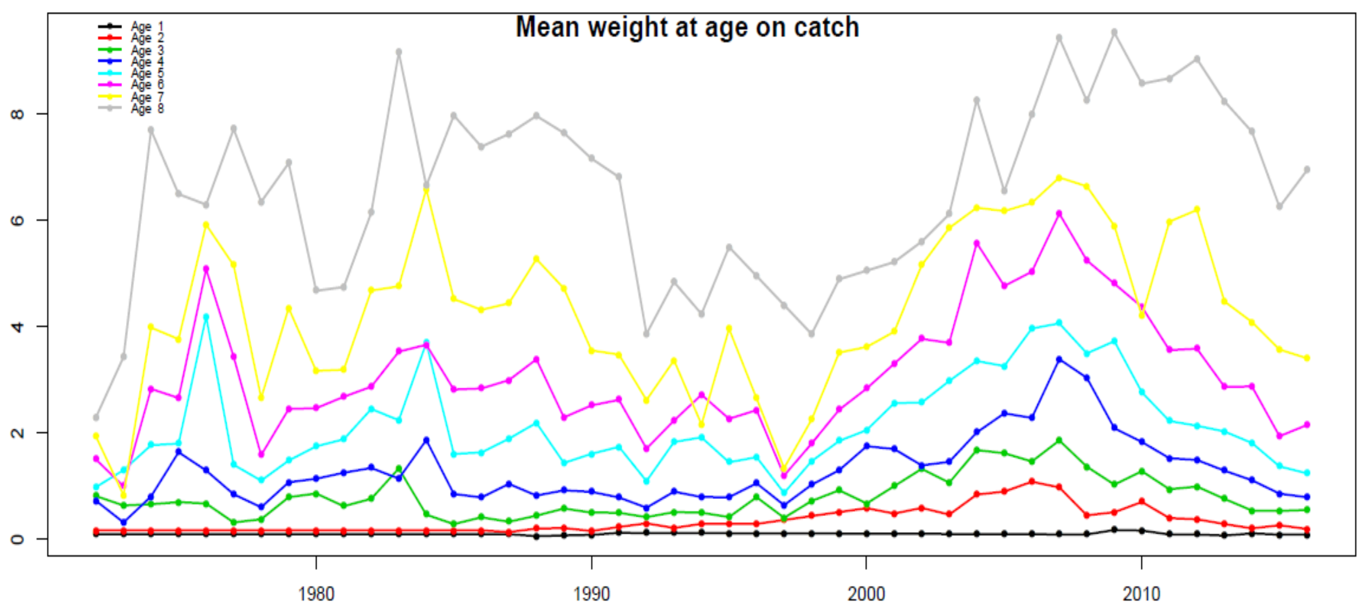


Fig. 6. Catch mean weight at age.

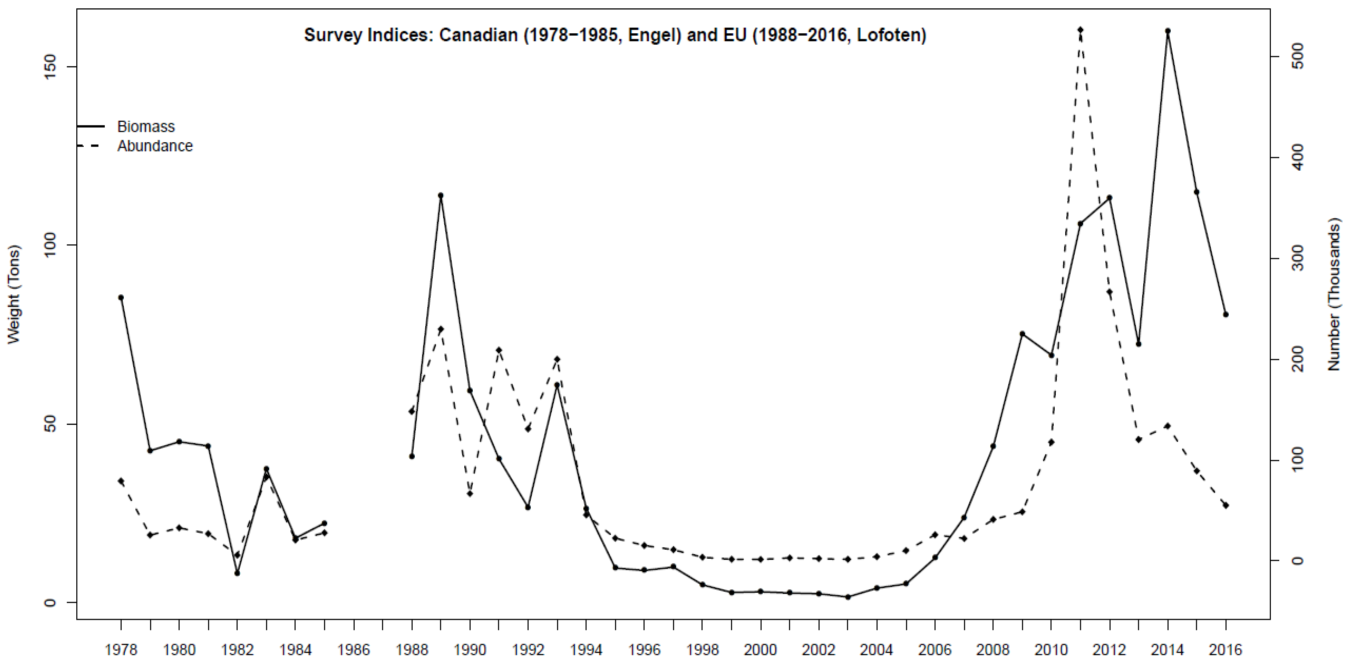


Fig. 7. Biomass and abundance from Canadian and EU surveys.

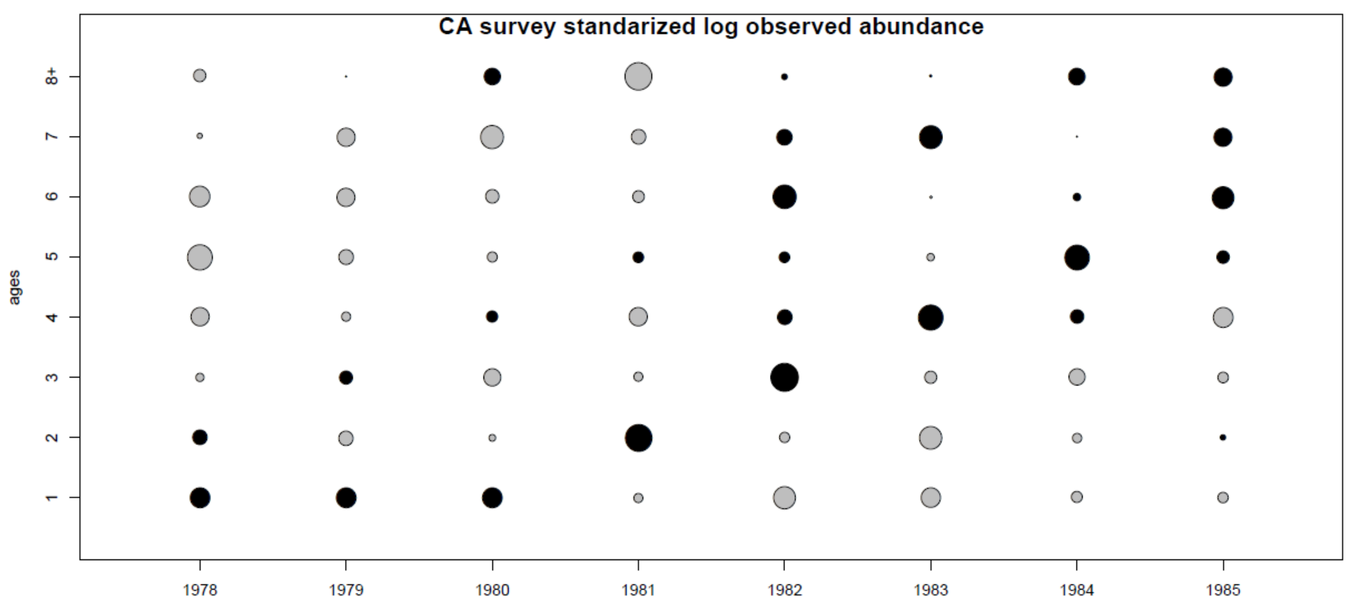


Fig. 8. Standardised log(1+Abundance at age) indices from Canadian survey. Grey and black values indicate values above and below the average. The larger the bubble size the larger the magnitude of the value.

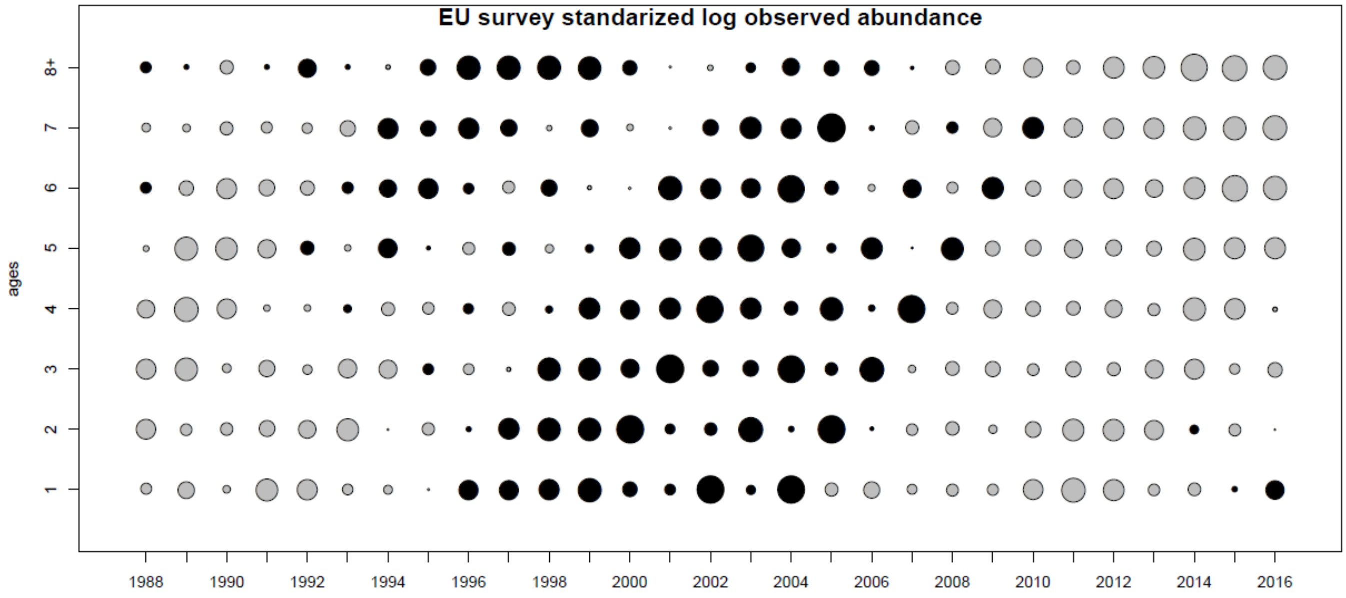


Fig. 9. Standardised log(1+Abundance at age) indices from EU survey. Grey and black values indicate values above and below the average. The larger the bubble size the larger the magnitude of the value.

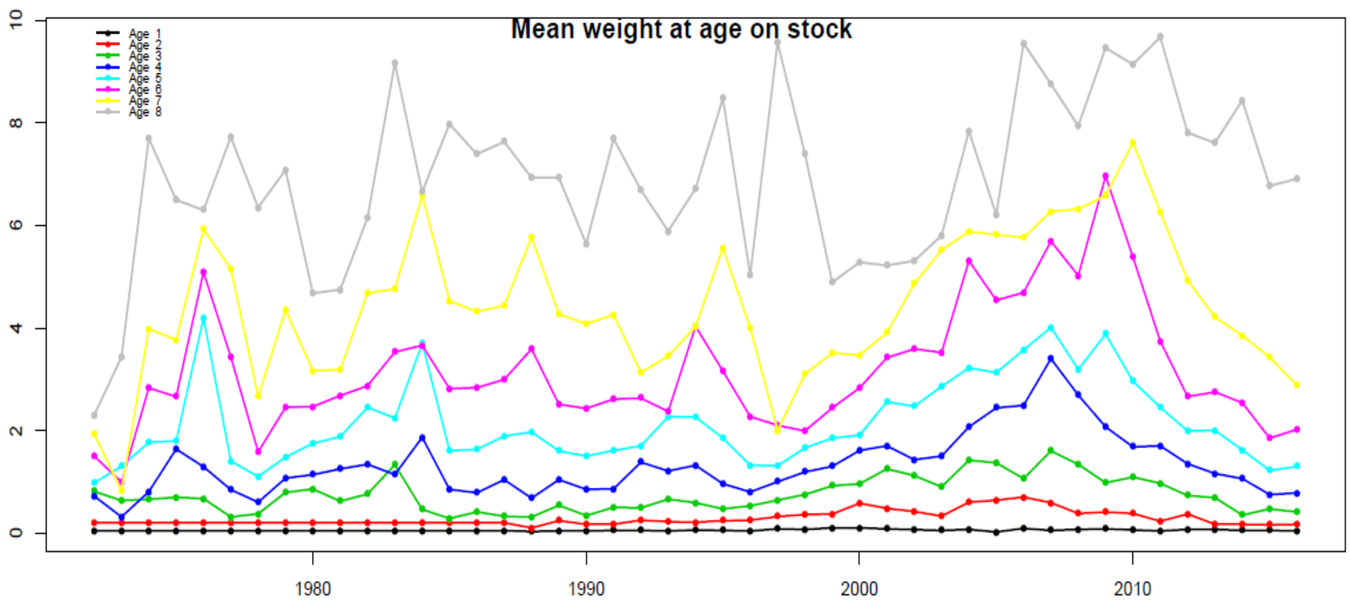


Fig. 10. Stock mean weight at age.

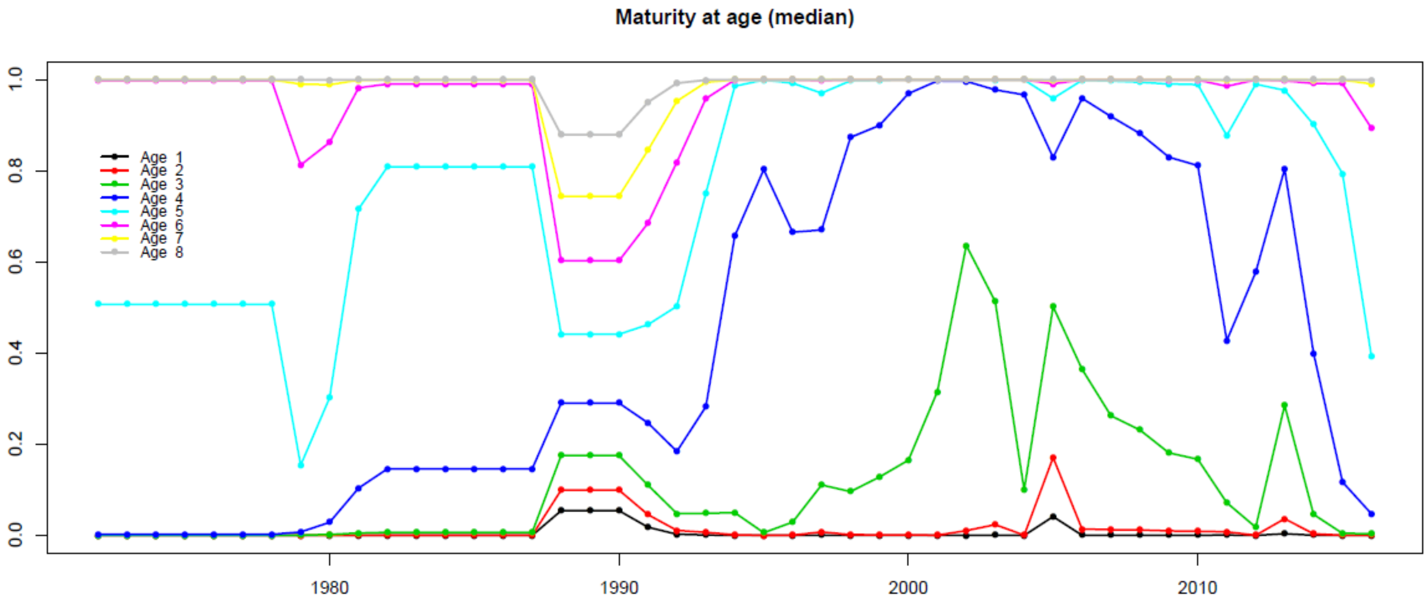


Fig.11 Maturity ogive by age.

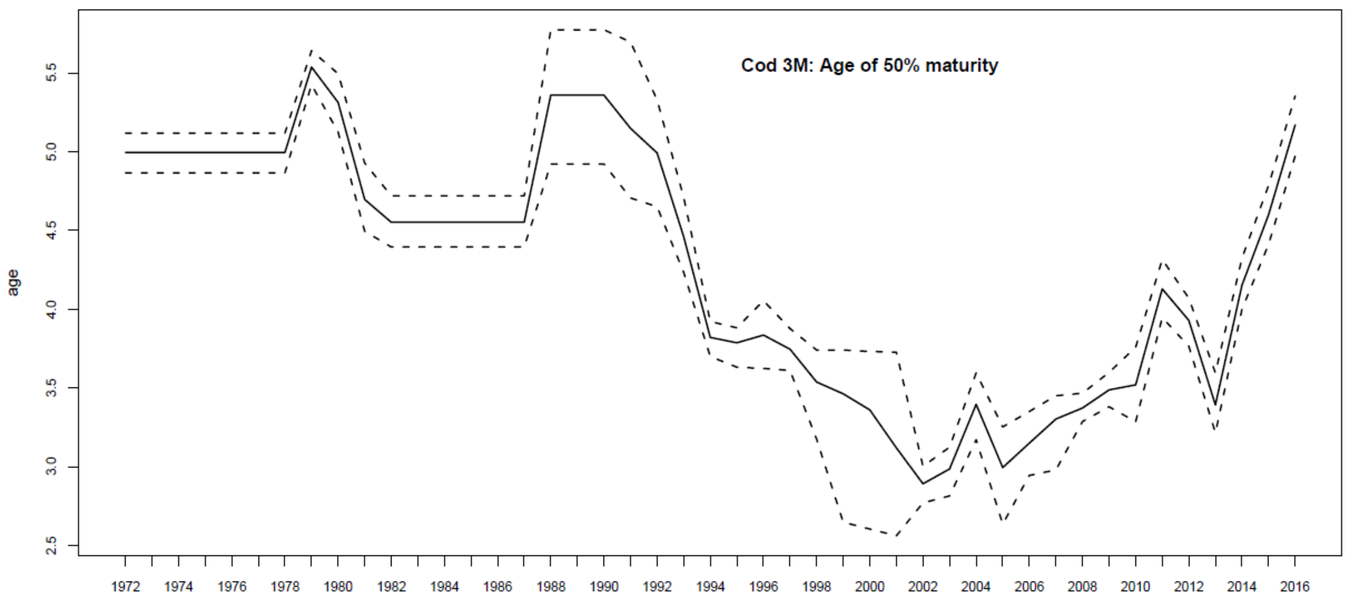


Fig. 12. Age at which 50% of fish are mature.

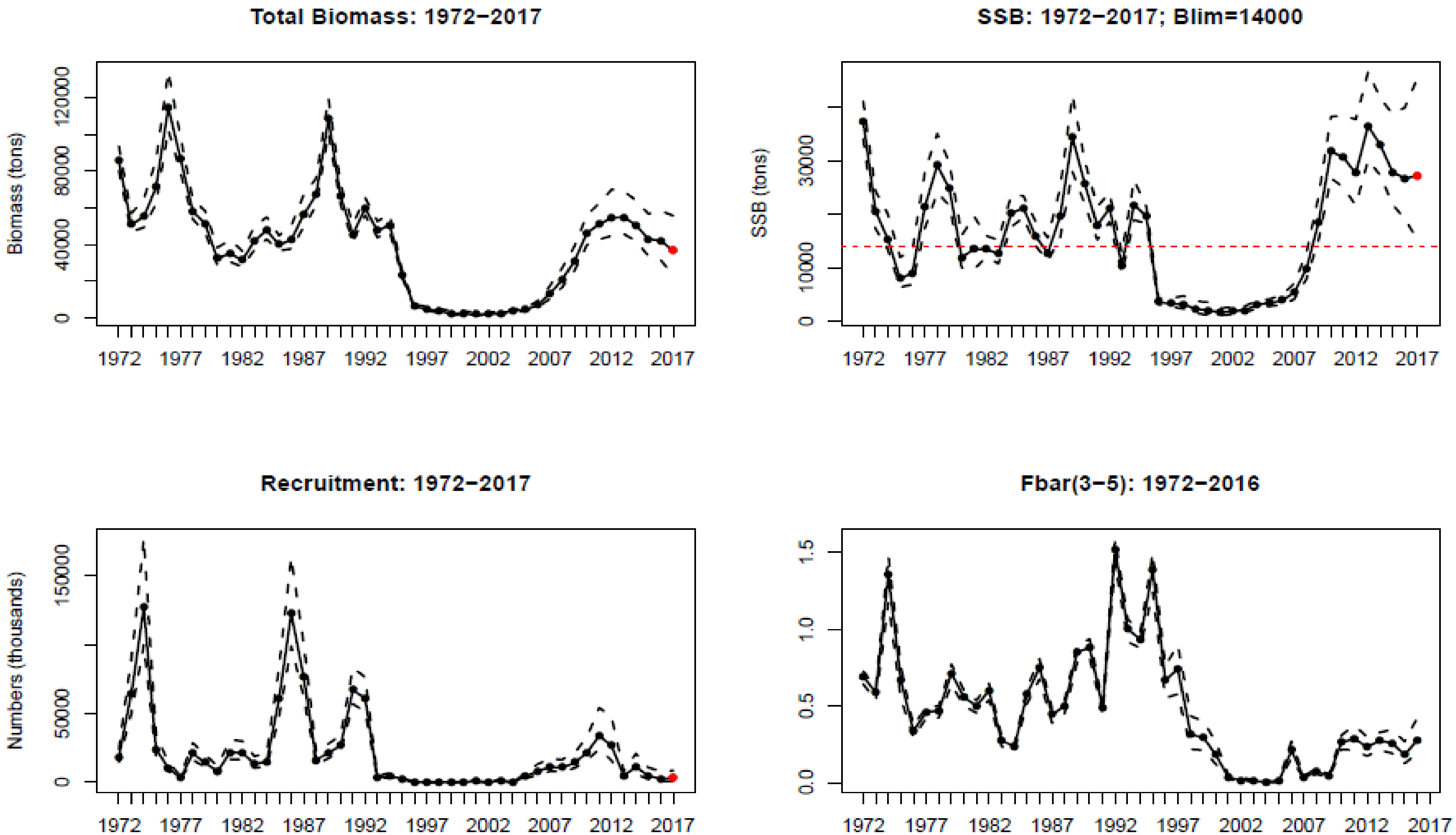


Fig. 13. Estimated trends in biomass, SSB, recruitment and F_{bar}. The solid lines are the posterior medians and the dashed lines show the limits of 90% posterior credible intervals. Red horizontal line in the SSB graph represents B_{lim} = 14 000 tons.

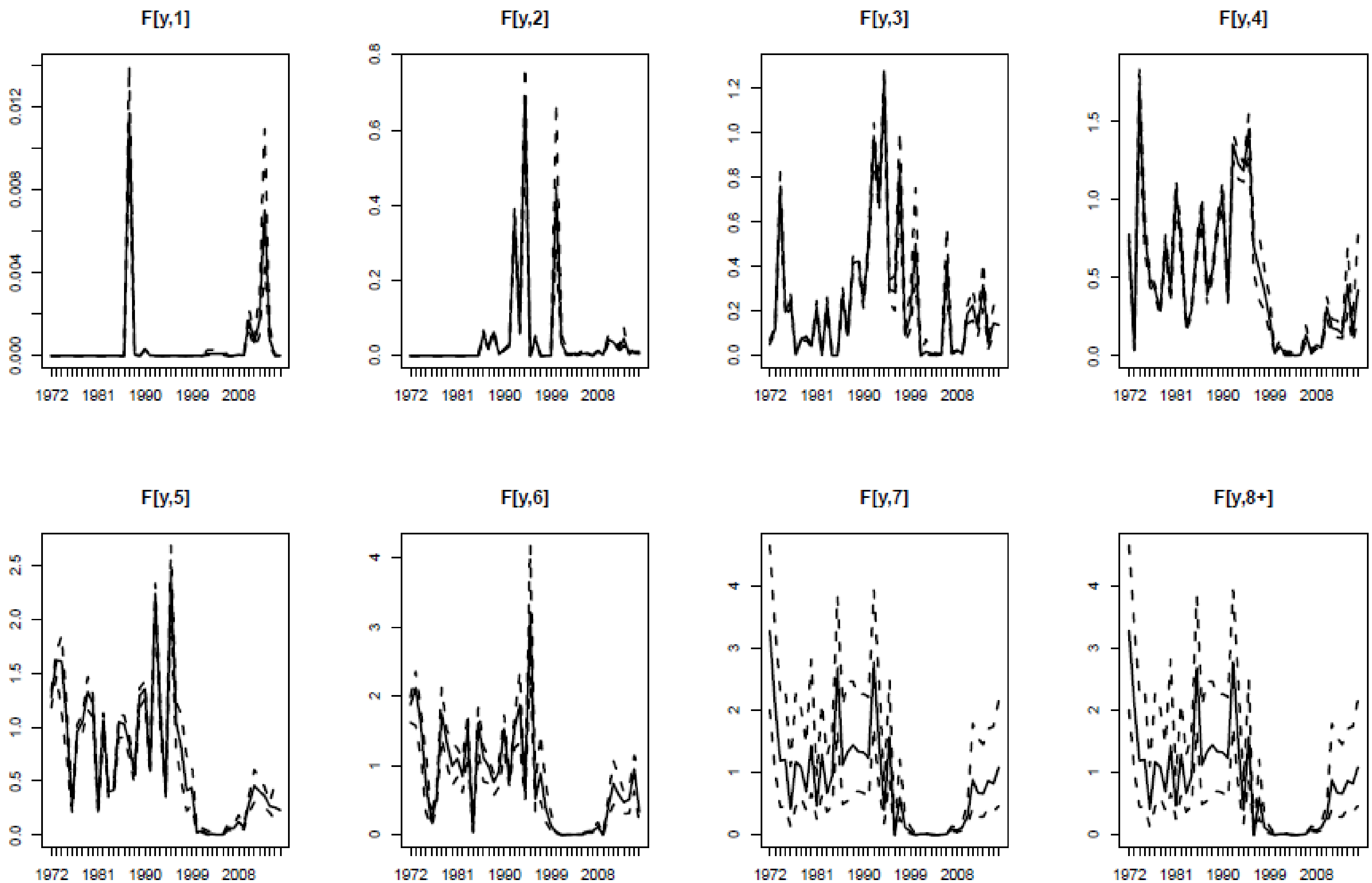


Fig.14. Estimated fishing mortality at age. The y-axis scale is different in all the graphs.

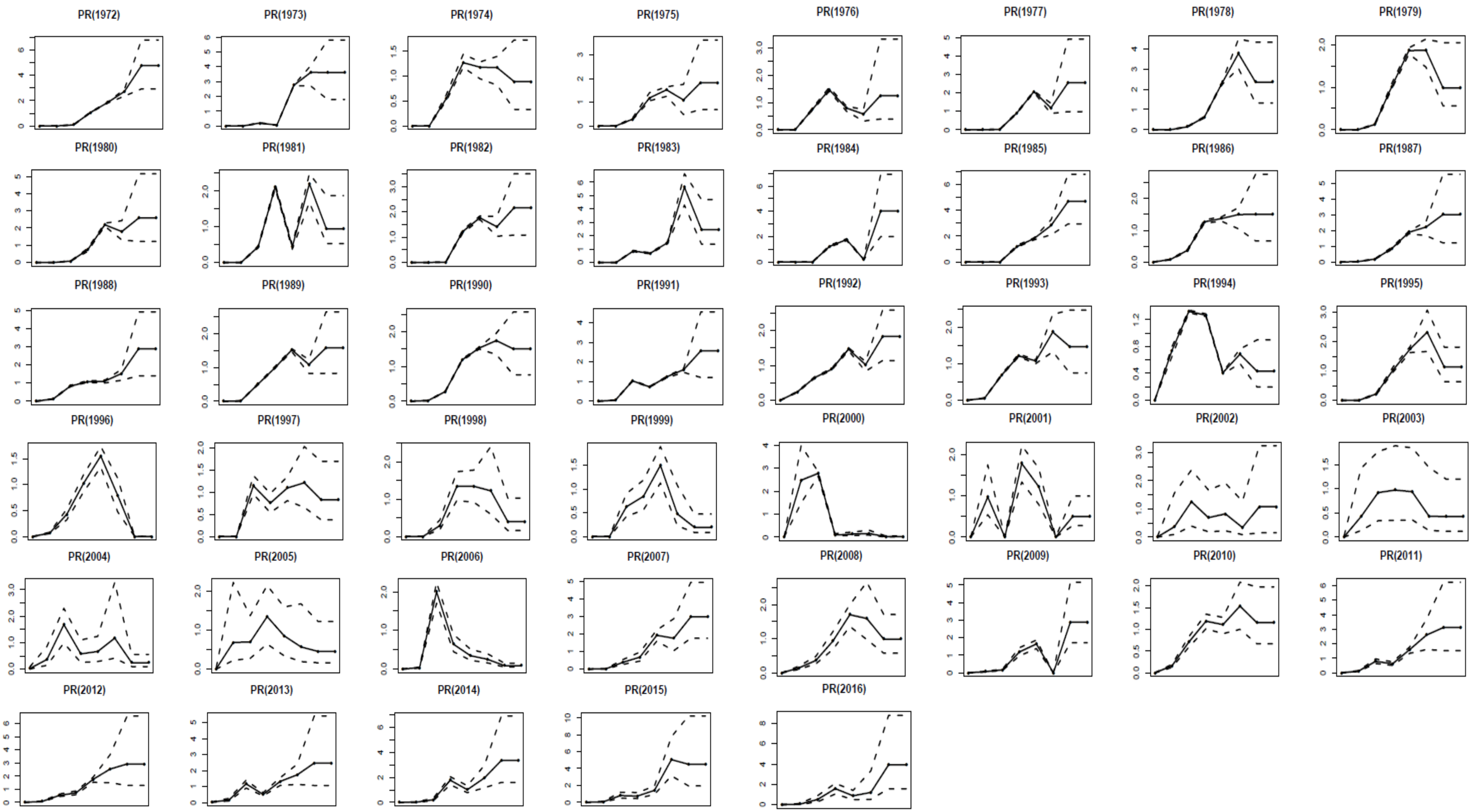


Fig. 15. Estimated PR (F/F_{bar}) per age and year. Take into account the different y-axis between figures.

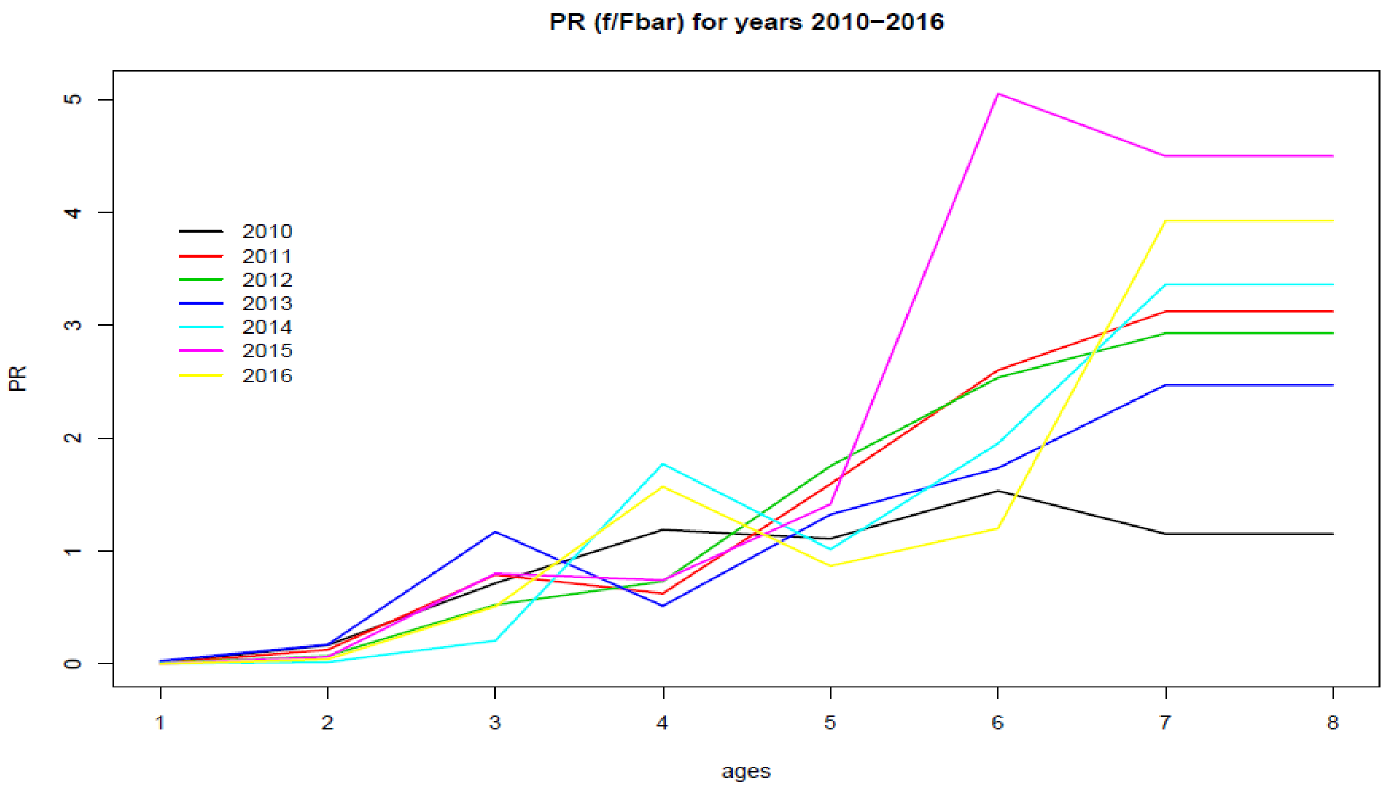


Fig. 16. Estimated PR (F/F_{bar}) per age for the last five years.

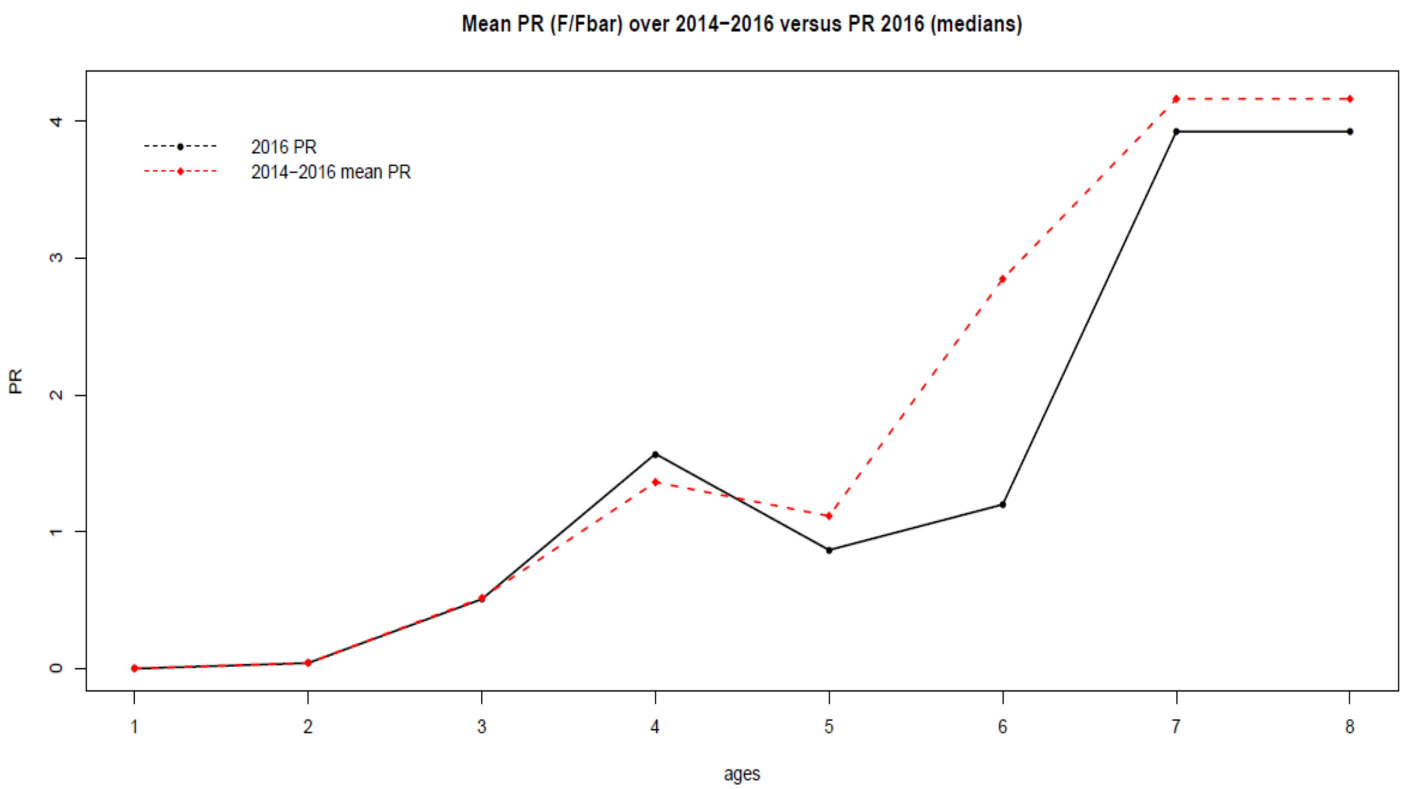


Fig. 17. Mean of 2014-2016 PR versus 2016 PR (posterior medians). Bold line is the mean of the last three years PR.

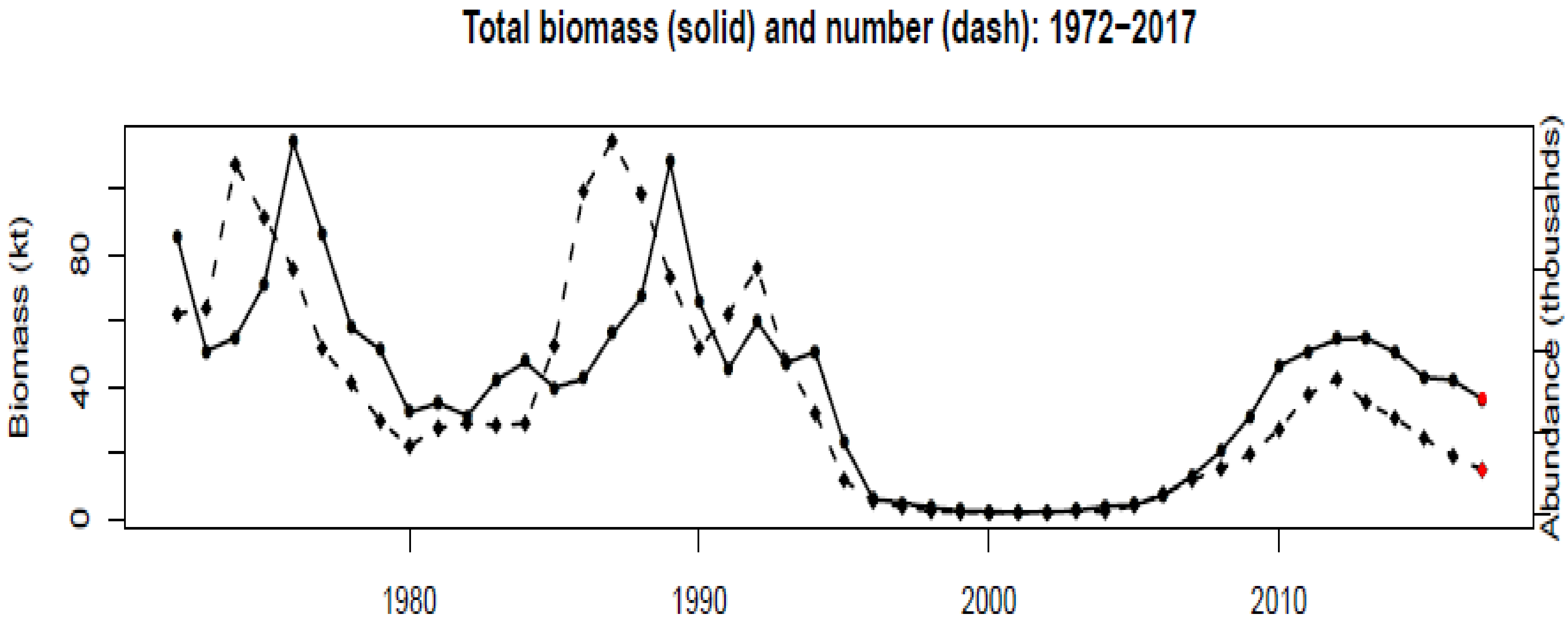


Fig. 18. Estimated trends in biomass and abundance.

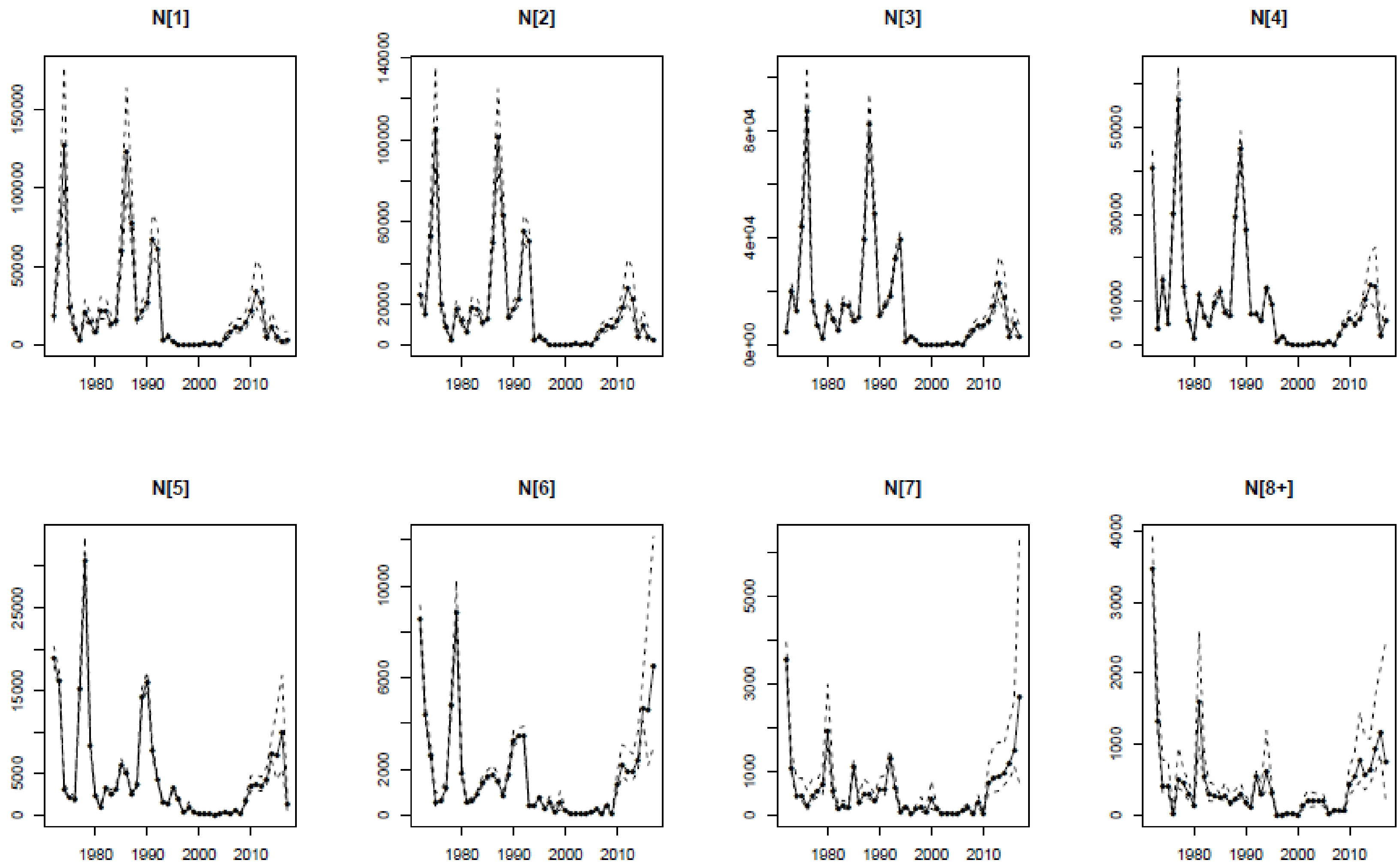


Fig. 19. Estimated numbers at age. The y-axis scale is different in all the graphs.

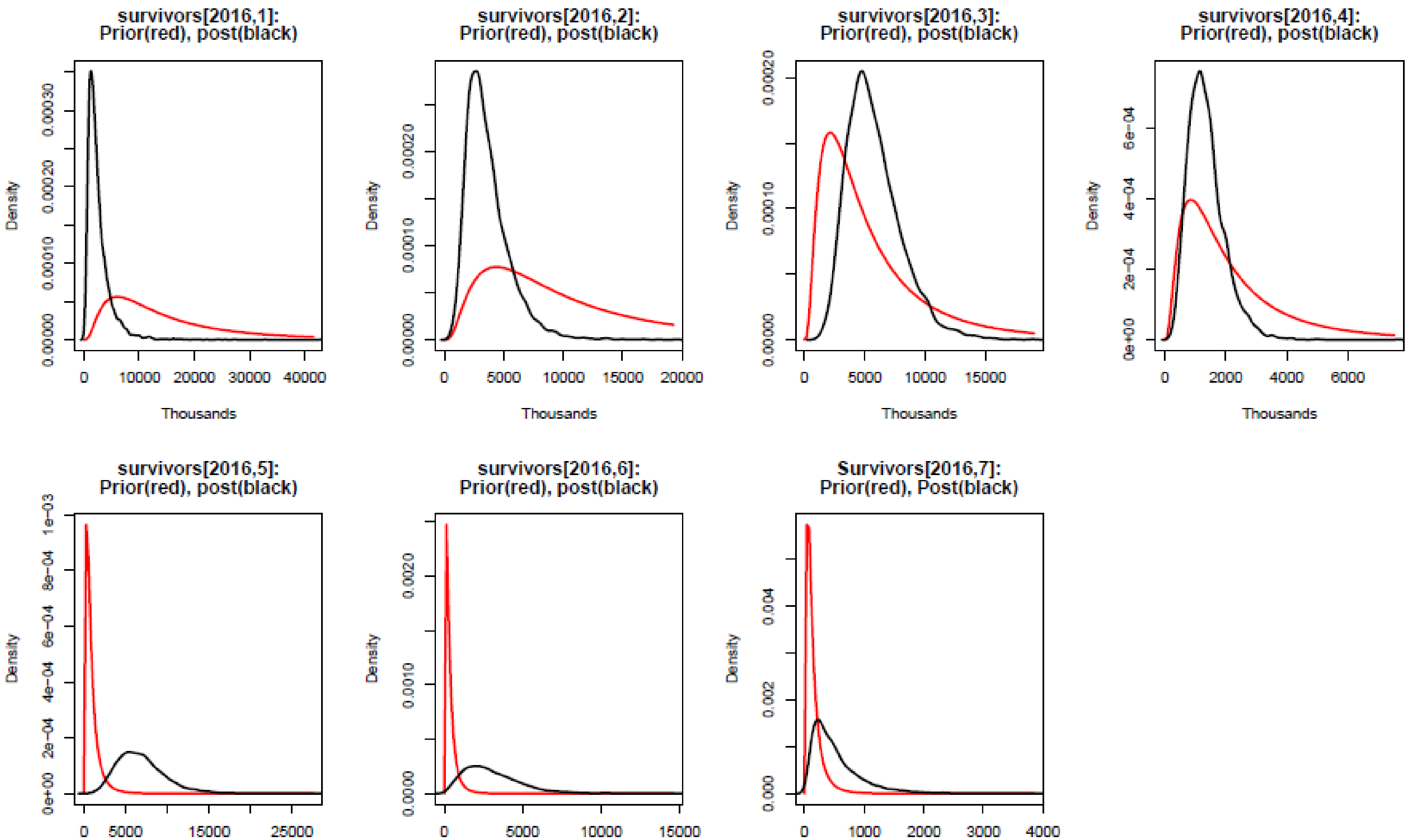


Fig. 20. Survivors at age at the end of 2016 (*survivors* (2016,a) are the number of individuals of age a+1 at the beginning of 2017). The y-axis scale is different in all the graphs.

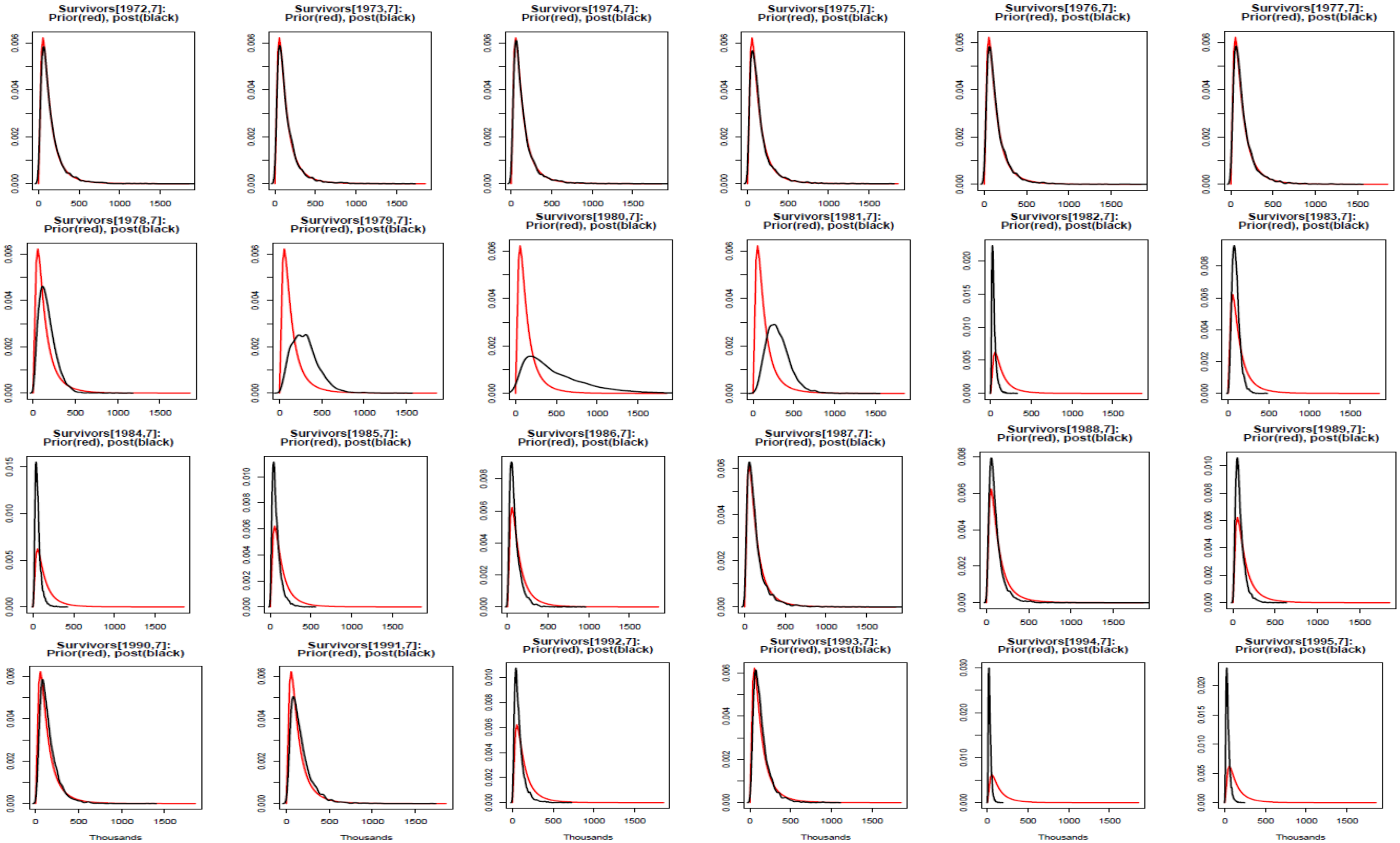


Fig. 21. Survivors from age 7 in each year (*survivors* (y,7) are the individuals of age 8 at the beginning of year y+1). The y-axis scale is different in all the graphs.

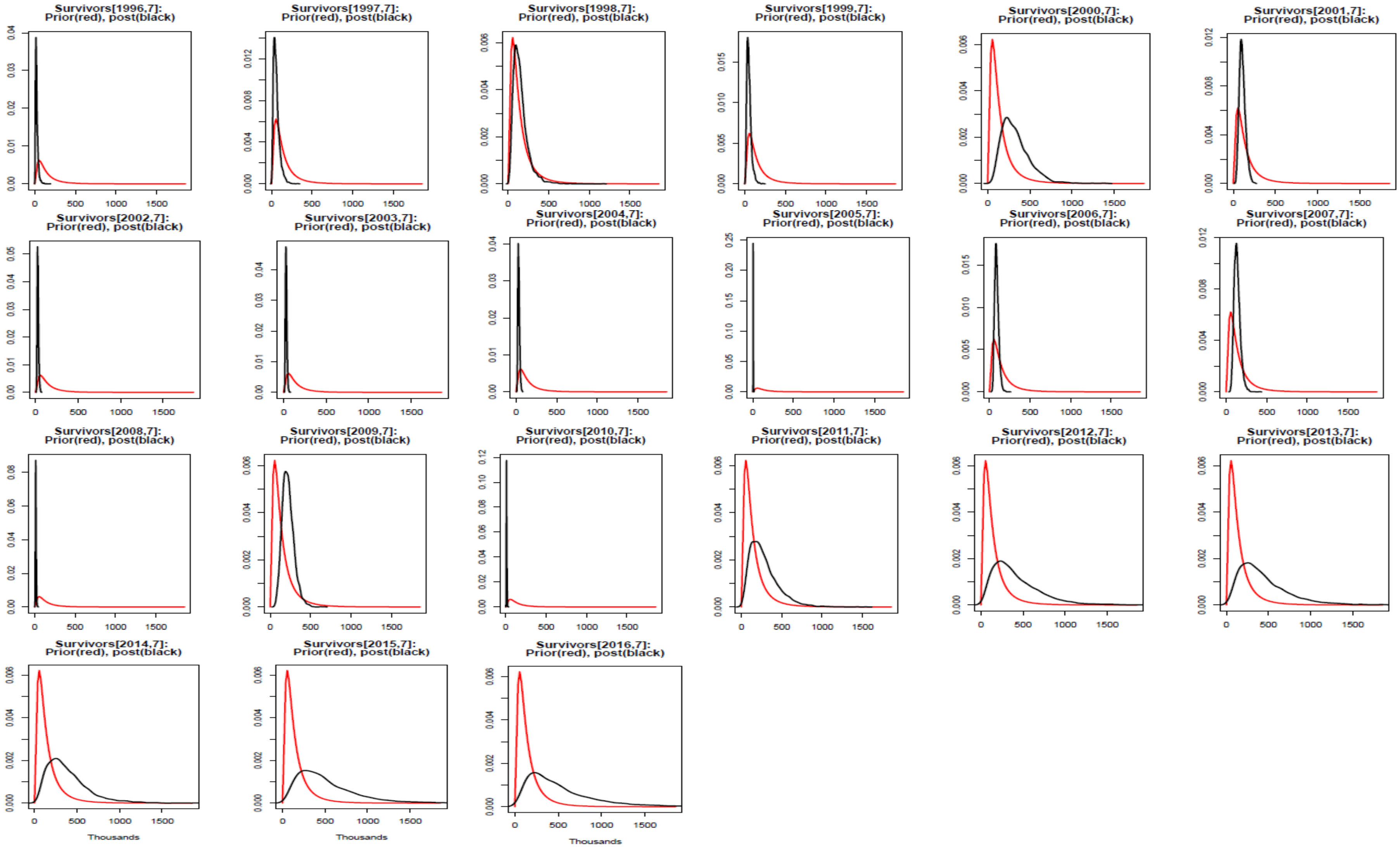


Fig. 21 (cont.). Survivors from age 7 in each year (*survivors* (y,7) are the individuals of age 8 at the beginning of year y+1). The y-axis scale is different in all the graphs.

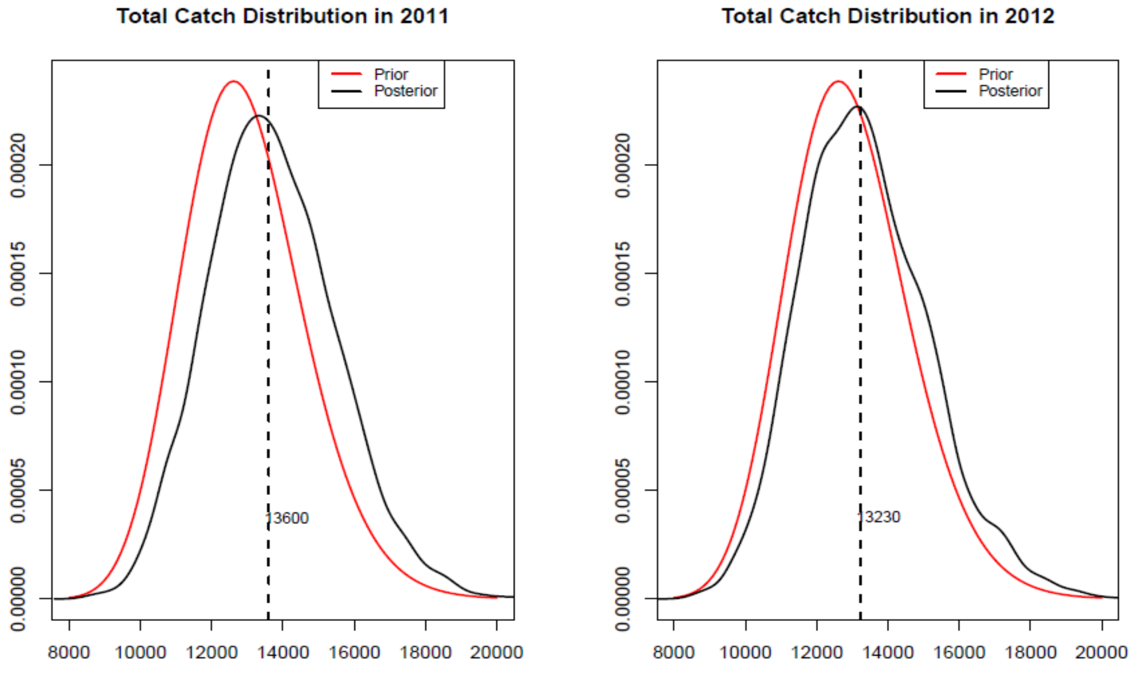


Fig. 22. Estimated total catch in 2011 and 2012.

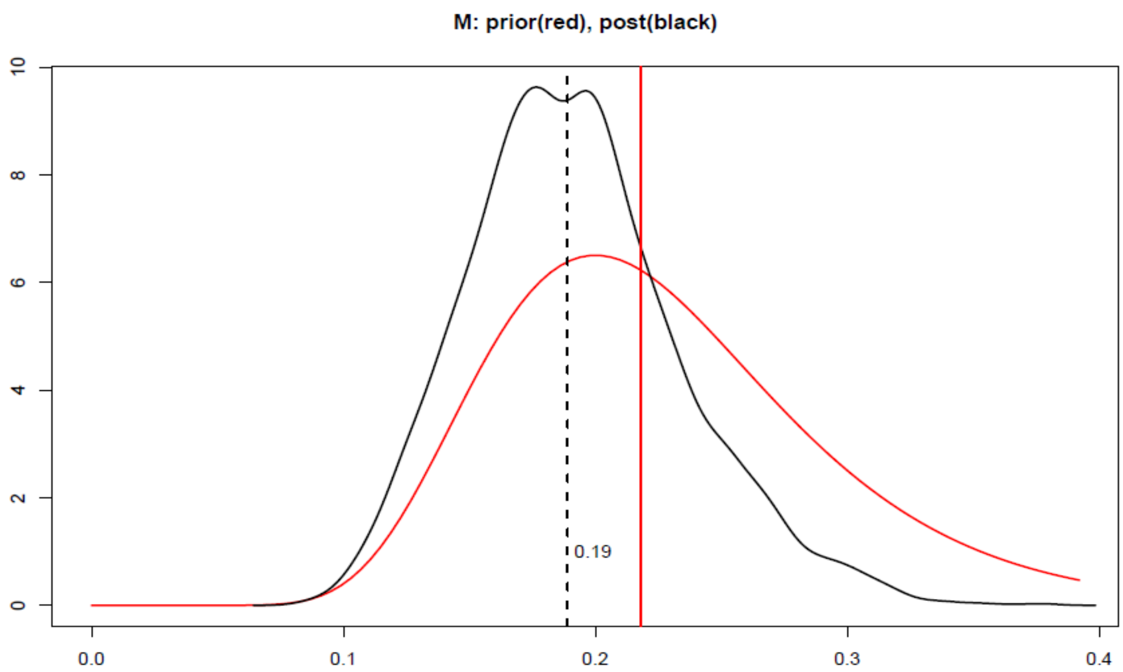
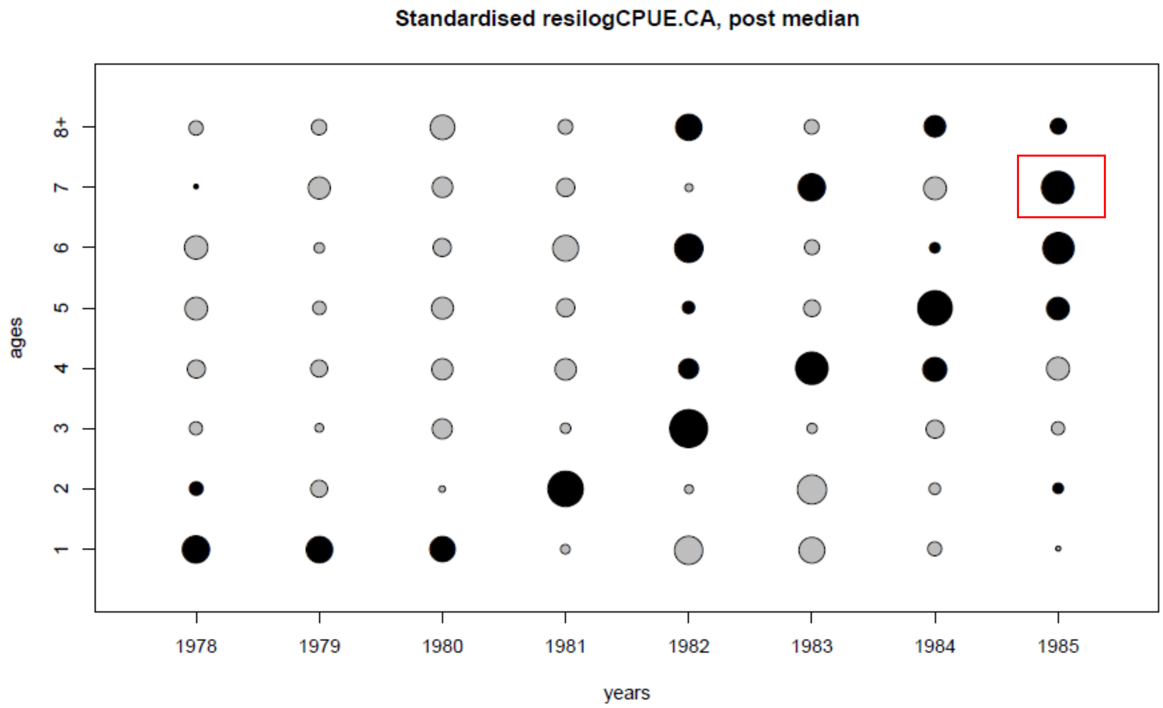


Fig. 23. Estimated natural mortality in 2016.



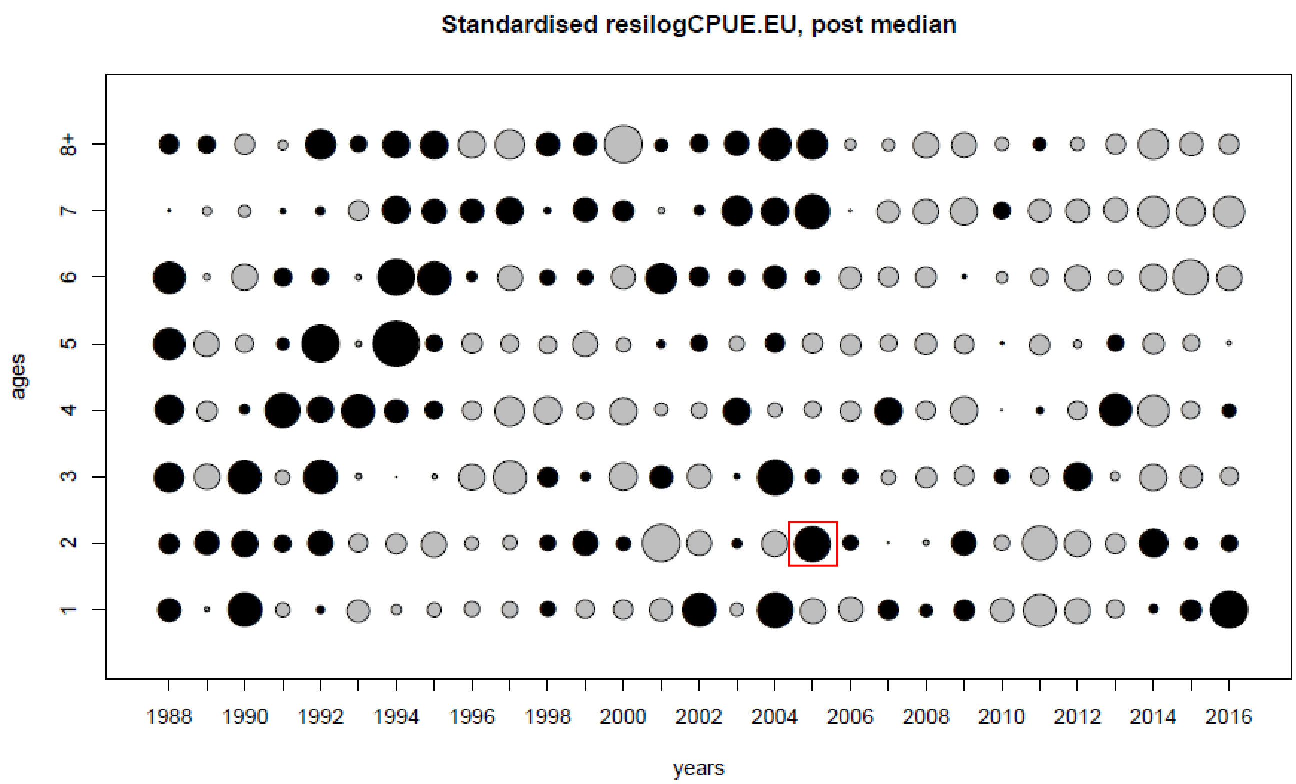


Fig. 24. Standardised residuals (observed minus fitted value) in logarithmic scale of survey abundance indices at age: Canadian and EU surveys. Grey and black values indicate values above and below the average. The larger the bubble size the larger the magnitude of the value. The red square indicates a bubble with a value near 2 (in absolute values).

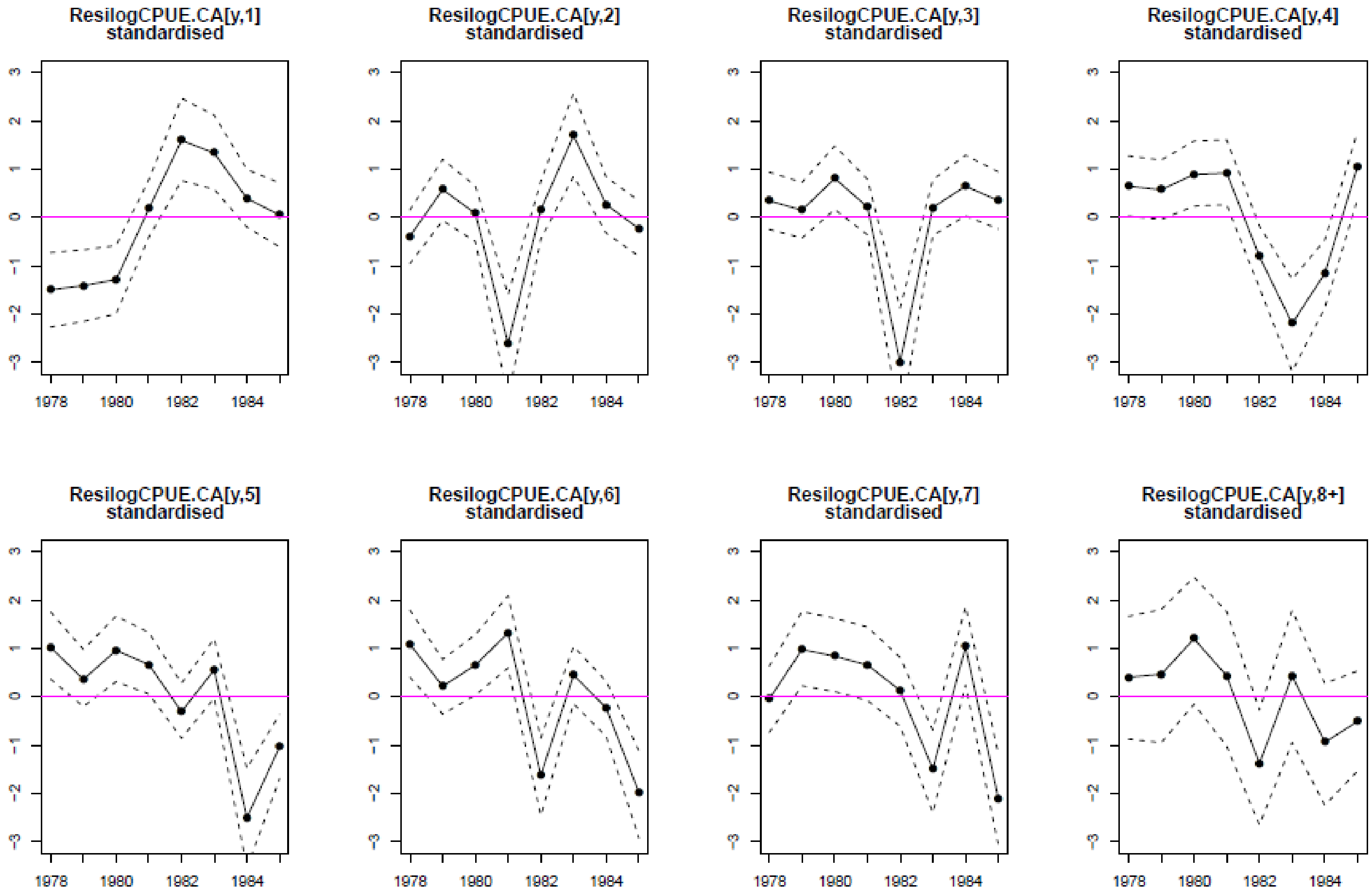


Fig. 25. Standardised residuals (observed minus fitted value) in logarithmic scale of survey abundance indices at age for Canadian survey by age.

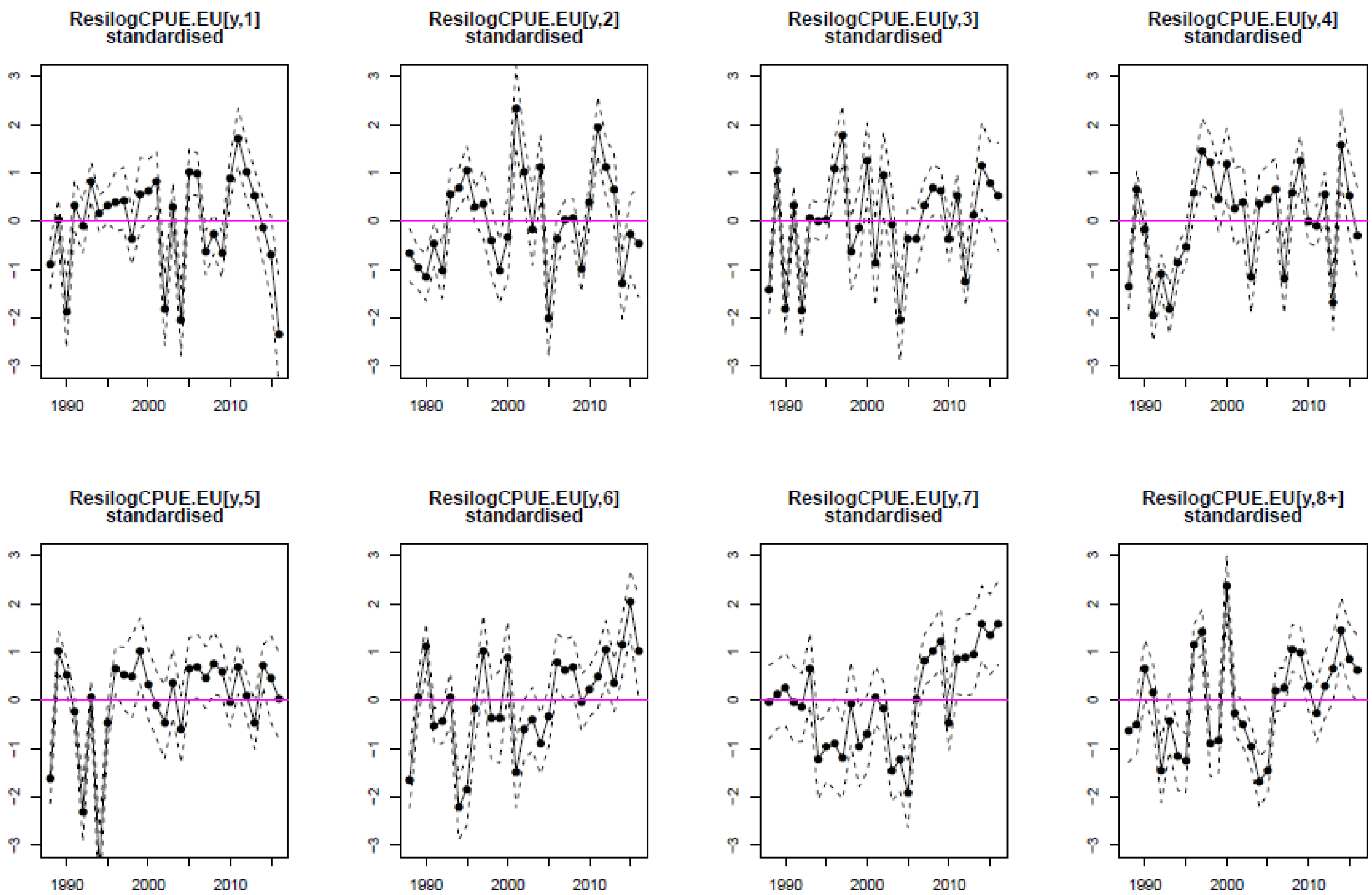


Fig. 26. Standardised residuals (observed minus fitted value) in logarithmic scale of survey abundance indices at age for EU survey by age.

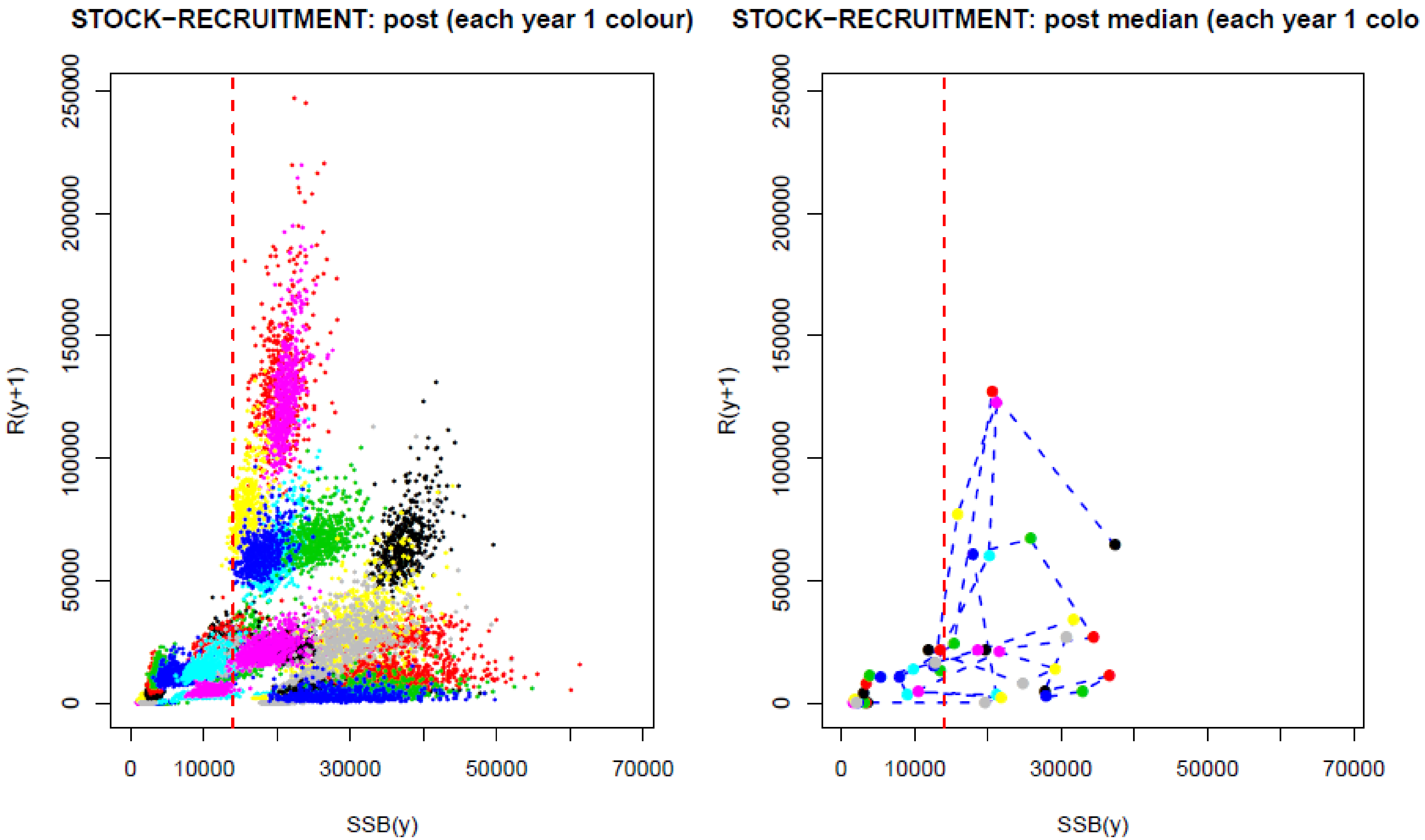


Fig.27. Stock-Recruitment plots. B_{lim}=14000 is shown as the red vertical line.

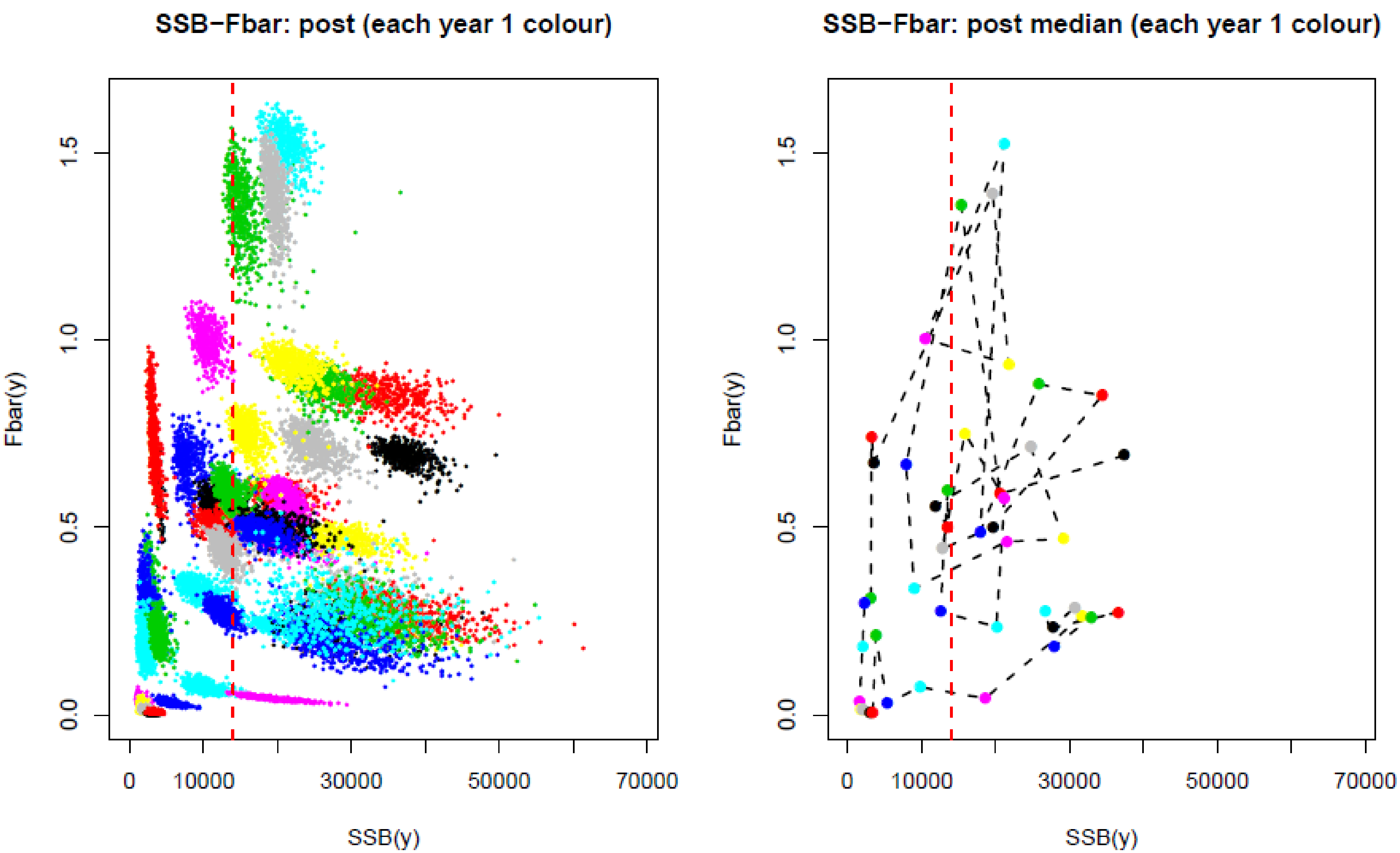


Fig. 28. F_{bar} versus SSB plots. B_{lim}=14000 is shown as the red vertical line.

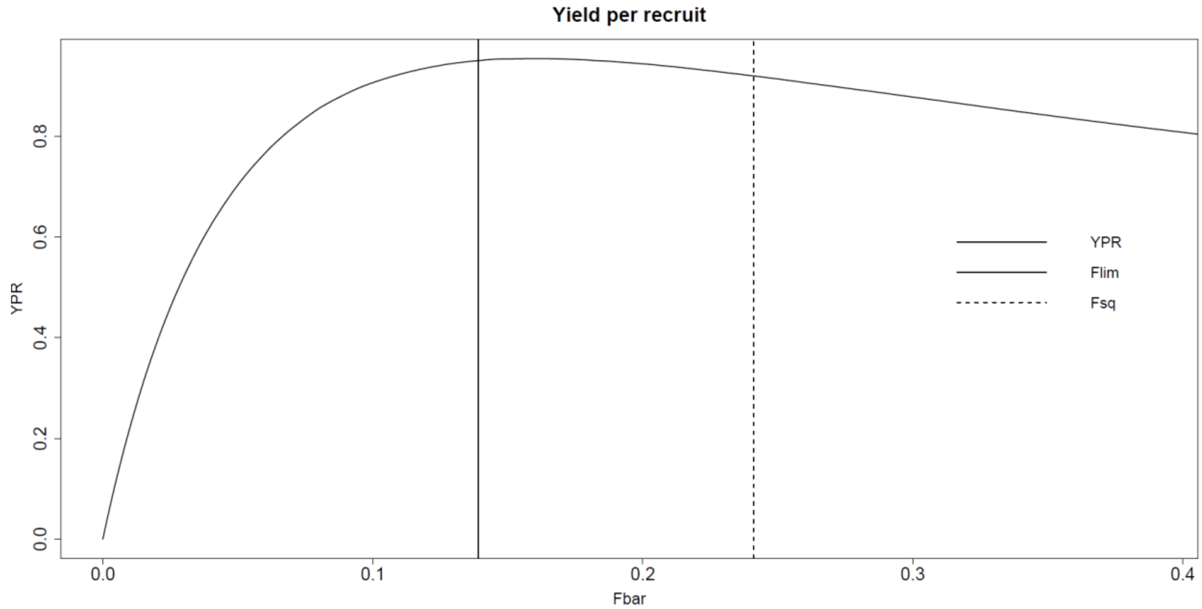


Fig. 29. Bayesian Yield per Recruit (1972-2016) versus F_{bar}. The values of F_{lim} ($F_{30\%SPR}$) and $F_{statusquo}$ (mean F over 2014-2016) are indicated.

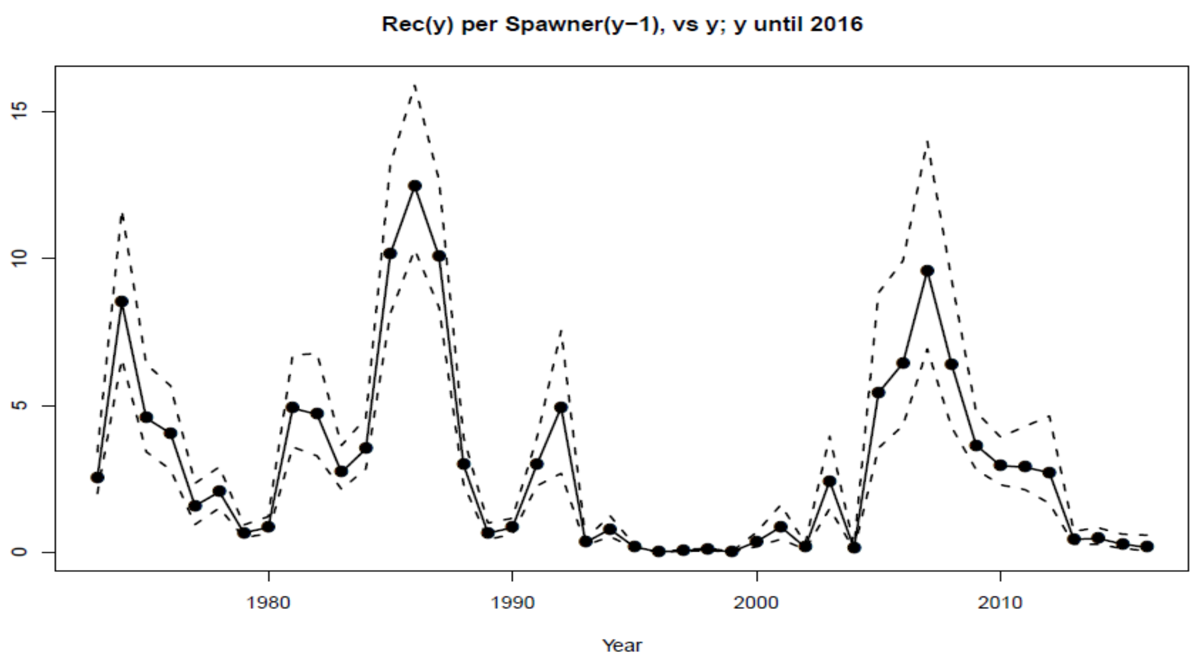


Fig. 30. Estimated recruits (age 1) per spawner.

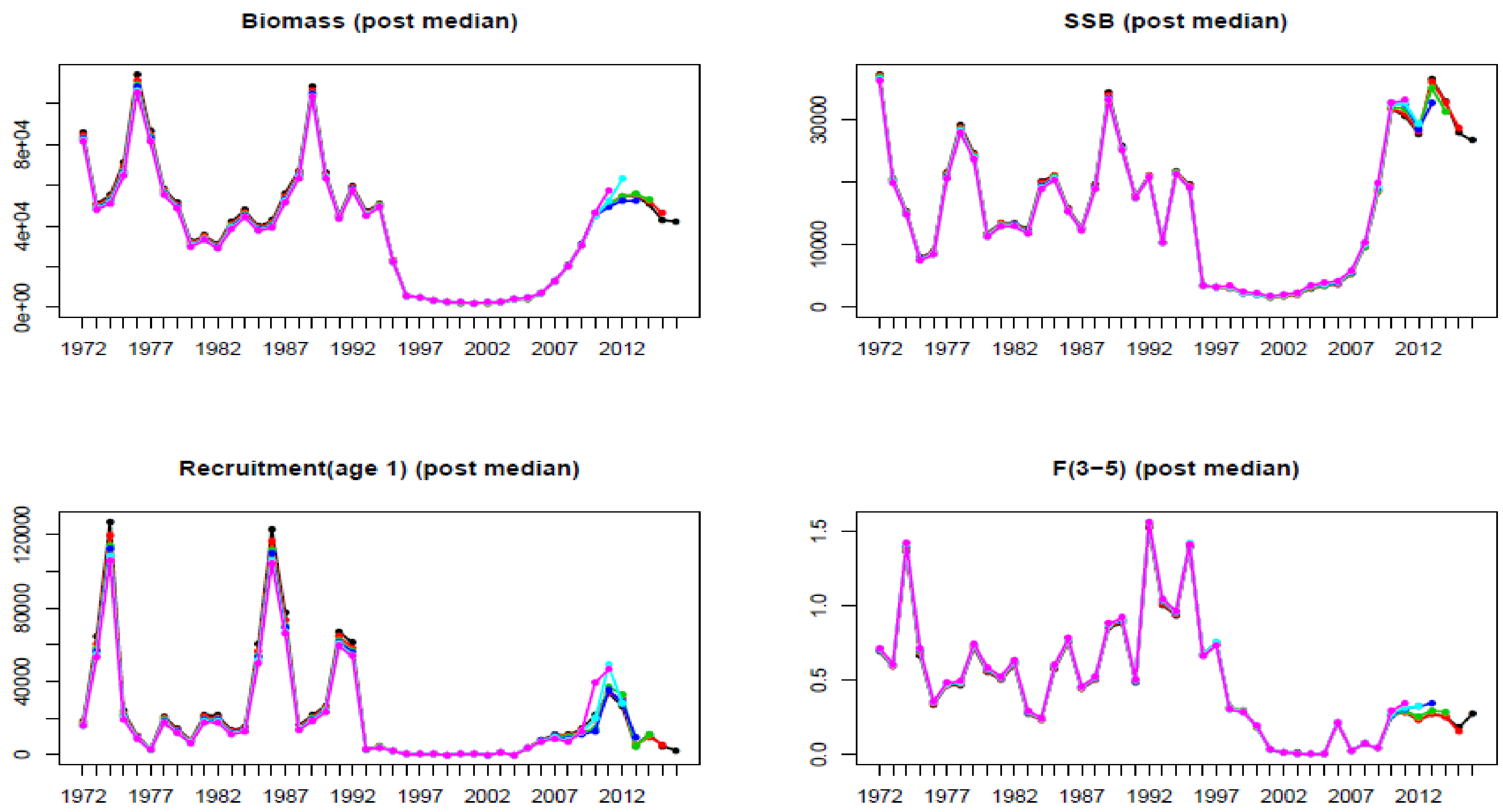


Fig. 31. Retrospective patterns.

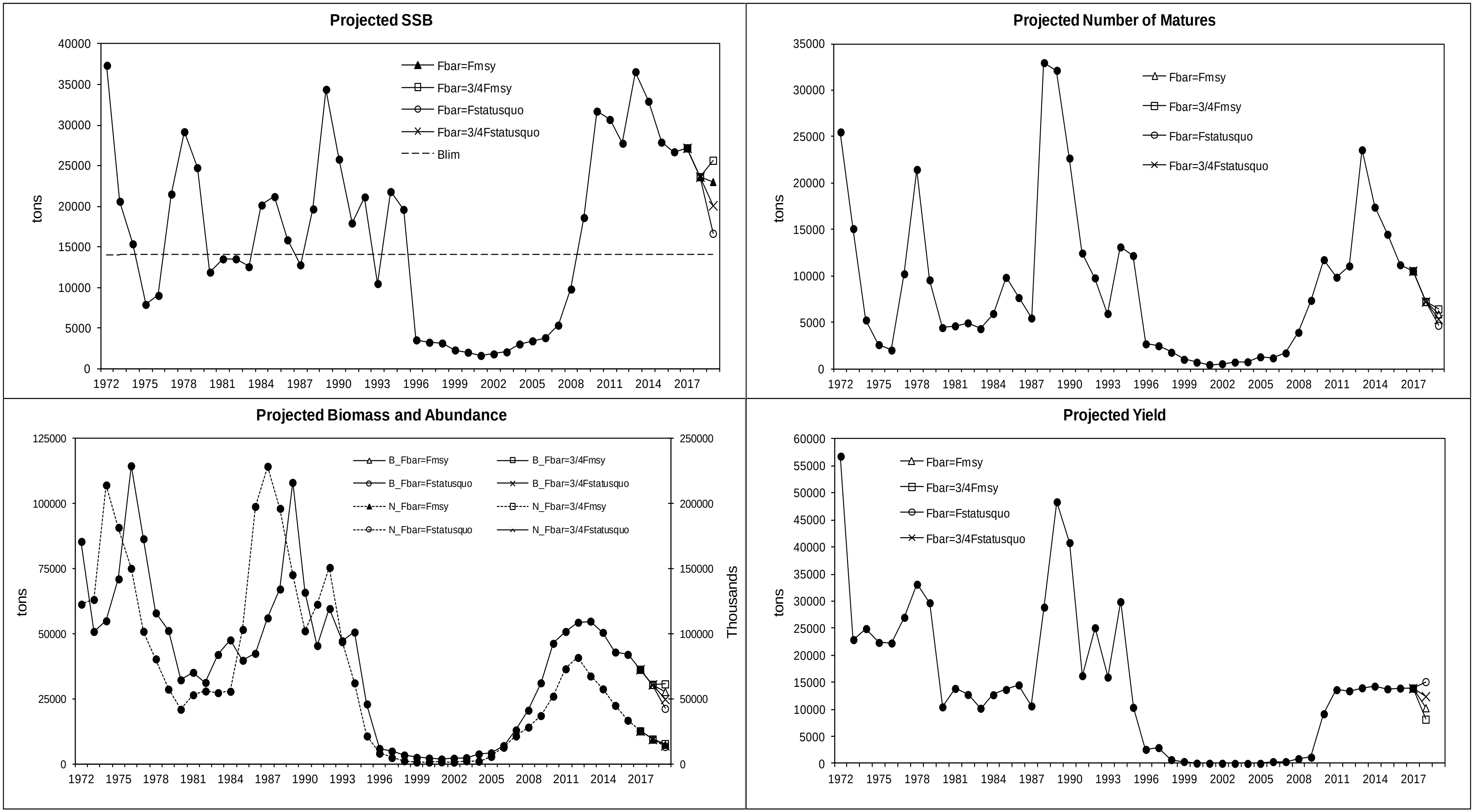


Fig. 32. Projections for SSB, number of matures, total Biomass and Yield with different scenarios.