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Cod 3M Projections: risk estimation and inputs

by

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Abstract

The last full assessment for the 3M Cod in the NAFO Scientific Council was carried out in June 2015, giving an advice for two years. Some problems concerning the NAFO 3M cod projections were identified during the 2015 Annual Meeting. Trying to solve these issues, a Workshop was organized by the EU in March 2017.

An issue raised by the Fisheries Commission in 2015 is that the risk of exceeding F_{lim} for some of the projection scenarios presented in the assessment was difficult to interpret in light of the overlap in credible intervals of the yields of the various options. To solve this issue, the authors developed a new projection method to perform the 3M cod projections and compute risk, projecting a single catch value instead of a distribution of catches.

One of the problems raised by the Scientific Council is how to estimate the inputs to be used in the projections due to the rapid changes in the biology of this stock, especially from 2007. Normally the last three years mean is used as input for these parameters. The changes in the biological parameters cause problems in the projections results as the inputs used for the projected years usually are overestimated, leading to an overestimation of the SSB and the associated TAC for a given F. To solve this issue, the authors suggest using just the last year inputs in the projections. An attempt to add uncertainty in the last year inputs was made, examining the interannual changes observed in past years in the inputs and taking into consideration the correlation between them. The uncertainty and the risk in the results increases considerably and it was suggested to study deeply this method before its implementation.

The authors conclude that caution should be exercised concerning the results of the projections for this stock. If uncertainty in the projection inputs is implemented, advice for more than one year will not be accurate due to the issues identified.

Introduction

In 2008 a Bayesian XSA model was introduced for the assessment of this stock. Several updates and improvements in model code (both for the assessment model and the projections algorithms) have been made since then. A benchmark of this assessment is planned for 2018. Scientific Council (SC) has listed issues to be investigated (NAFO, 2015a).

One of the main issues raised by the Scientific Council is that the inputs (mean weight in catch, mean weight in stock and maturity ogive) used in the projections (generally the mean of the last three years) are overestimated for the projection years due to the rapid changes in the biology of this stock, especially from 2007. This leads to an overestimation of biomass, SSB and Yield in the projection years.

Another problem raised by the Fisheries Commission in 2015 (NAFO, 2015c) is that the risk of exceeding F_{lim} for some of the projection scenarios presented in the assessment was difficult to interpret in light of the overlap in credible intervals of the yields of the various options. This leads to an extensive discussion within STACFIS on the methods used to calculate risk (NAFO, 2015b). Although the SC concluded that there was no computation error, the SC acknowledged that the risk proposed did not correspond to the expected one.

A Workshop organized by the European Commission under the Specific Contract No. 03 (SC03) under Framework Contract EASME/EMFF/2016/008 *Provision of Scientific Advice for Fisheries beyond EU Waters* was held in Vigo in March 2017, to try to address, among others, the above mentioned issues of the 3M Cod current assessment. This document presents a new method to estimate the risk in the projections and a way to implement uncertainty in the projections input parameters.

Material and Methods

Assessment data

The last full assessment for the 3M Cod in the NAFO Scientific Council was carried out in June 2015 (González Troncoso, 2015), with data until the end of 2014. In this paper, the last approved assessment was updated to include the 2015 data.

-Total Commercial catch, 1972-2015: Table 1, Figure 1

-Catch-at-age in catch, 1972-2015: Table 2

-Weight-at-age in catch, 1972-2015: Table 3 and Figure 2

-Canadian bottom trawl survey abundance at age, 1978-1985: Table 4

-EU bottom trawl survey abundance at age, 1988-2015: Table 5

-Weight-at-age in stock, 1972-2015: Table 6 and Figure 3

-Maturity at age and age of first maturation , 1972-2015: Table 7 and Figure 4

The maturity ogive used in the 3M cod assessment is estimated each year separately, using a logistic model with a Bayesian fit as following:

$$MO_{y,a} = \frac{1}{1 + e^{-\beta_{2,y}(a-\beta_{1,y})}}$$

We have 5000 different values β_1 and β_2 for each year, from which a maturity ogive by age is calculated as presented in Table 7.

There are some gaps in the series of mean weights in catch and 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.

<u>Assessment model</u>

The last approved assessment (González-Troncoso, 2015) has been updated with the 2015 data.

<u>Projections</u>

Projections method and risk

The methodology to perform projections and calculate risk used for this stock until now and the new one proposed by the authors are explained next.

Assume that we have a stock assessment containing data until year Y (e.g. 2015). The stock assessment is conducted with a Bayesian model and 5000 samples from the posterior distribution, calculated by MCMC, are used to summarize stock assessment results and to provide starting points for the projections. The projections are done iteration by iteration, independently for each of the 5000 iterations, in the following way for each iteration:

For each iteration, the survivors at age from the last year in the assessment, Y (2015), become the numbers at age+1 at the start of year Y+1 (2016). With these population numbers, the known TAC for Y+1, and the assumed partial recruitment and weights-at-age for the projection, the corresponding F-at-age in Y+1 and the survivors at the end of the year are estimated. The survivors become the population numbers (incrementing age by 1) at the start of Y+2. Fisheries Commission scenarios based on F options start at this point (Y+2) and continue in the incoming projected years.

Projections for Y+2 are performed with a given F (usually F_{lim}, $3/4F_{lim}$, $F_{statusquo}$ and $3/4F_{statusquo}$) estimated iteration by iteration, resulting in a catch for Y+2 for each iteration, i.e. 5000 catch values. The NAFO SC catch advice for the stock corresponds to the median of the 5000 catch values. The main problem issue described below would also occur if F_{lim} and $F_{statusquo}$ were defined as single values.

From here onwards the projection and risk computation methodology proposed by the workshop differs from the one used until now. The differences are in:

(a) the risk associated with the advised catch for Y+2 is calculated differently;

(b) the population numbers at the end of year Y+2 are calculated differently; therefore, the starting population numbers for projections for years after Y+2 are different.

Concerning point (a):

The risk of F exceeding F_{lim} in year Y+2 was calculated up to now by comparing F in Y+2 with F_{lim} iteration by iteration, based directly on the F in Y+2 used in the projection described above. This meant that, for example, for the catch option corresponding to $F=3/4F_{lim}$, the P(F in Y+2 > F_{lim})=0; even though the distribution of catches in Y+2 corresponding to $F=3/4F_{lim}$ overlaps with the distribution of catches corresponding to F_{lim}. The projection has been conducted in such a way that F in Y+2 was always exactly equal to $3/4F_{lim}$ and, therefore, the probability that F in Y+2 exceeds F_{lim} is zero.

Taking into account that the way the risk was calculated is mathematically correct, we do not consider this measure of risk appropriate in this case because this calculation does not correspond to a particular catch value in Y+2, but to an entire distribution (arising from the 5000 iterations) catch values. However, the eventual TAC that will be set for Y+2 will be a single value, so it makes more sense to calculate the risk that F exceeds F_{lim} for that single catch value in Y+2 instead for a catch distribution, especially taking into account the wide distribution of the catches for a given F (Figure 5). The new proposal is, therefore, to measure the risk associated with a single catch value instead of the risk associated with an entire distribution of catch values. In other words, the proposal is to calculate the distribution of Fs in Y+2 that arise from a single catch value in Y+2, where this single catch value is the median of the 5000 catch values obtained for Y+2 from the procedure above. The risk of F exceeding F_{lim} in year Y+2 is then calculated, just as before, by comparing F in Y+2 with F_{lim} iteration by iteration.

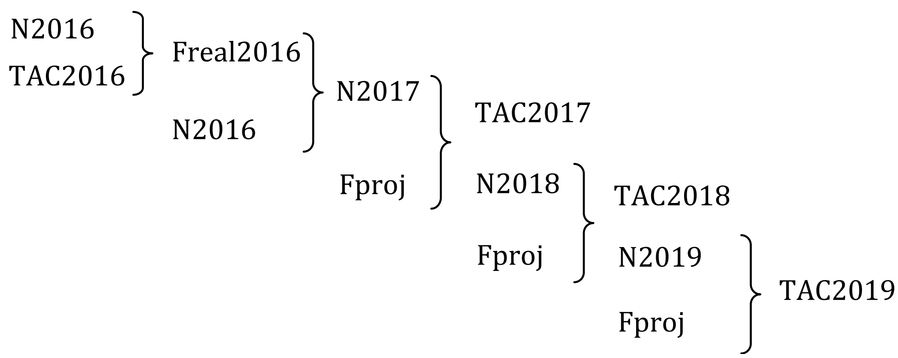
Continuing with the example of the catch option corresponding to $F=3/4F_{lim}$, the Fs calculated in the new proposed way for Y+2 will no longer all be identical to $3/4F_{lim}$; 50% of them will be above and the rest below $3/4F_{lim}$, and the risk of F exceeding F_{lim} will in almost all cases be greater than zero.

Concerning point (b):

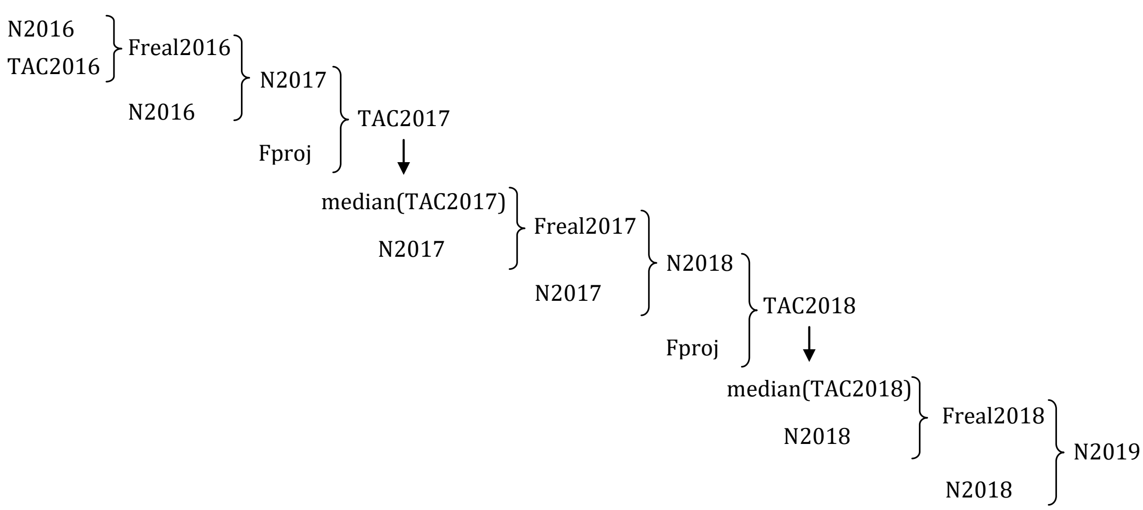
With the new way of computing risk, based on projecting though Y+2 with a fixed catch value in Y+2, population abundances at the end of Y+2 can also be calculated and will differ from those obtained from the previous projections method. Any projections for years after Y+2 will start from these population abundances, instead of the ones calculated from the previous projections method.

The following two schemes show the steps in the projection methodology used until now and in the new methodology we propose, being F_{proj} the projected F in each projection Scenario.

Projection methodology used until now:



Projection methodology proposed by the authors:



Inputs to the stock projections

The mean weights (both in stock and in catch) and the maturity at age have a decreasing trend since 2007 (Figures 2, 3 and 4), so the mean of the last three years, traditionally used to estimate the values of the inputs of the starting year of the projection, has consistently been overestimating the reality of that year. This decreasing trend is more marked in the case of the mean weights, for which the 2015 data for ages younger than 7 years are around 50% of their values in the 2010 data, whereas for older ages this is around 60%-80%.

These decreasing trends could be explained in part by density-dependent effects. There is a clear negative correlation between the abundance and the mean weights and some maturities at age, mostly at ages 3-5 (Figure 7).

These trends in the biological parameters cause problems in the projections results as the inputs used for the projected years usually are overestimated, leading to an overestimation of the SSB and the associated TAC for a given F.

One way to reduce the impact of this overestimate in the projections results could be to use as inputs the weights and ogives of the last year instead of the current last three years mean.

In the case of this stock, the inputs of the projections have no uncertainty incorporated except in the case of the maturity ogive. Uncertainty in the projections' inputs to account for possible changes in biological parameters from one year to the next was also analyzed by examining the interannual changes observed in past years. As the mean weights in catch, the mean weights in stock and the maturity ogive are biologically correlated, it seems reasonable to take this correlation into account when modelling the uncertainty. Doing so, strange values in the projections' inputs can be avoided (e.g. the combination of a very high mean weight in stock together with a very low mean weight in catch). Analyzing the distribution of the interannual changes in these parameters during the assessment period (1972-2015) it can be observed that their distributions do not look too different from a normal distribution (Figure 8) with a mean of 0, both with and without taking logarithms of the parameters. Therefore, it was decided to use a multivariate normal distribution to generate the uncertainty for the three input parameters (mean weights at age in catch and stock, and maturity at age) as follows:

$$\varepsilon = MultiNormal(n = 5000, \mu = 0, \sigma = cov(\Delta\ln(MWC), \Delta\ln(MWS), \Delta\beta_1, \Delta\beta_2))$$

where cov is the empirical covariance matrix (calculated based on the values of these parameters in past years) of $\Delta\ln(MWC)$, $\Delta\ln(MWS)$, $\Delta\beta_1$, and $\Delta\beta_2$, which represent the following interannual changes:

$$\Delta\ln(MWC_{y,a}) = \ln(MWC_{y,a}) - \ln(MWC_{y-1,a}) \quad \text{for } y\text{=1973-2015}, \quad a\text{=1-8+}$$

$$\Delta\ln(MWS_{y,a}) = \ln(MWC_{y,a}) - \ln(MWC_{y-1,a}) \quad \text{for } y\text{=1973-2015}, \quad a\text{=1-8+}$$

$$\Delta\beta_{1,y} = \beta_{1,y} - \beta_{1,y-1} \quad \text{for } y\text{=1973-2015}$$

$$\Delta\beta_{2,y} = \beta_{2,y} - \beta_{2,y-1} \quad \text{for } y\text{=1973-2015}$$

where MWC is the mean weight in catch, MWS the mean weight in stock, and β_1 and β_2 are the parameters of the Bayesian logistic model used to calculate the maturity ogive by age.

We have 5000 different values β_1 and β_2 for each past year, from which the medians of β_1 and β_2 in each of those years were calculated and then used as the basis to generate projection uncertainty due to interannual variability as described above.

We took the logarithm for the mean weights both in catch and stock in order to avoid possible negative values of the weights used as inputs in the projections.

In summary, we have an 18 dimensional covariance matrix that reflects the correlation by age between the interannual differences of the mean weight in catch, mean weight in stock and the maturity ogive logistic parameters. Therefore, 18 correlated errors (interannual deviations) from the multivariate normal are generated in each iteration (8 for the mean weight in catch, one for each age - $\varepsilon_{MWCY,a}$-, 8 for the mean weight in stock, one for each age - $\varepsilon_{MWSY,a}$-, and 2 for the maturity ogive - $\varepsilon_{\beta 1,Y}$ and $\varepsilon_{\beta 2,Y}$). The mean weights in catch and stock and maturities at age for each iteration in the projected years will be generated from the values observed in the last year (Y) and these interannual deviations as:

$$MWC_{Y+1,a} = CMW_{Y,a} * e^{\varepsilon_{MWCY,a}} \quad \text{for } a\text{=1-8}$$

$$MWS_{Y+1,a} = SMW_{Y,a} * e^{\varepsilon_{MWSY,a}} \quad \text{for } a\text{=1-8}$$

$$MO_{Y+1,a} = \frac{1}{1 + e^{-(\beta_{2,Y}+\varepsilon_{\beta 2,Y})[a-(\beta_{1,Y+}+\varepsilon_{\beta 1,Y})]}}$$

Figure 9 shows pairwise scatterplots of the interannual changes observed in the historic data in ln(mean weights) in catch and stock and the two maturity parameters (numbers in the figure are the empirical correlations), and Figure 10 shows similar scatterplots of the values generated from the multivariate normal described above. In other words, the values in Figure 10 are the $\varepsilon_{MWCY,a}$, $\varepsilon_{MWSY,a}$ and $\varepsilon_{\beta 1,Y}$ and $\varepsilon_{\beta 2,Y}$ generated interannual deviations, which will be used to include uncertainty in the weights and maturity for the projections. The interannual changes in maturity parameters display very little correlation among themselves or with the interannual changes in weights. However, some considerable positive correlations can be observed between the interannual changes of the weights.

Figure 11 presents a comparison between the weights and maturity in the last year (2015) and the values generated by the method above including uncertainty (median and 90% confidence interval) due to interannual variation. For weights in catch and in stock, the medians of the generated values with uncertainty are the same as the 2015 values, with the uncertainty increasing with age. In the case of the maturity ogives, the 2015 values have themselves uncertainty (a logistic maturity ogive was estimated by a Bayesian model, as explained above), so the median and the confidence interval are presented for both the 2015 values and the values generated by the method above. In this case the medians are not exactly the same but are very close; the confidence interval is larger in the case of the inputs generated by the method above (capturing interannual variability) than for the 2015 values, as might be expected. Figure 12 shows pairwise scatterplots of the mean weights in catch and stock and the maturity ogives in the projected years (numbers in the figure are the empirical correlations). There are some considerable correlations between the mean weights in stock and catch at the same age, mainly for the older ages. The maturity ogives do not seem to be highly correlated with the weights of the same age.

Results

Assessment

The main results of the assessment, using data until 2015, are shown in Table 8 and Figure 13 (Biomass, SSB, R and F_{bar}). The values at the beginning of 2016 are reflected in some graphs, although the recruitment is estimated. The Natural Mortality, M, is estimated inside the model (assumed to have the same value for all ages and years). The values of M estimated by different assessments since the reopening of the fishery are given in Table 9.

Projections

Stochastic projections have been performed from 2016 to 2019. Four different projection scenarios were applied: one scenario is as in the last approved assessment (Proj1), and the other three scenarios use the projections and risk methodology proposed by the workshop but with different inputs: one case (Proj2) uses the mean of the last three years, another one (Proj3) uses the values of the last year (Proj3), and the last one

(Proj4) uses the values of the last year adding uncertainty in weights and maturity as described earlier in this document. The inputs of the projections are:

Proj1: Method as in the last approved assessment

Population numbers aged 2 to 8+ in 2016: estimates from the assessment

Recruitments for 2016-2019: Recruits per spawner were estimated for each year and were drawn randomly from 2012-2014. The 2015 value was omitted due to uncertainty in estimating the recruitment in the final assessment year.

Maturity ogive for 2016-2019: Mean of the last three years (2013-2015) maturity ogive.

Natural mortality for 2016-2019: 2015 natural mortality from the assessment results.

Weight-at-age in stock and weight-at-age in catch for 2016-2019: Mean of the last three years (2013-2015) weights.

PR at age for 2016-2019: Mean of the last three years (2013-2015) PRs.

F_{bar}(ages 3-5): One option is considered, F_{bar}=3/4F_{lim} (median value = 0.100), assuming that the 2016 catch is the TAC (13 931 tons).

$F_{statusquo}$ was established as the mean fishing mortality over 2013-2015.

Proj2: Method proposed in this SCR

The inputs are the same as in Proj 1, just change the method to compute risk and perform projections to the one proposed in this document an described above.

Proj3: Method proposed in this SCR

Same method and inputs as Proj2, with the following difference in the inputs:

Maturity ogive for 2016-2019: Last year (2015) ogive

Weight-at-age in stock and weight-at-age in catch for 2016-2019: Last year (2015) weights.

Proj4: Method proposed in this SCR

Same method and inputs as Proj2, with the following difference in the inputs:

Maturity ogive for 2016-2019: Last year (2015) ogive + interannual variability via a Multivariate Normal distribution for weights and maturity.

Weight-at-age in stock and weight-at-age in catch for 2016-2019: Last year (2015) weights + interannual variability via a Multivariate Normal distribution for weights and maturity.

In Proj4, it should be noted that although the Multivariate Normal distribution is introduced to account for interannual changes, the same weights and maturity at age have been assumed for all projected years (2016-2019).

Although the projections for this stock are generally conducted for four options for F (F_{lim}, 3/4F_{lim}, F_{sq} and 3/4F_{sq}), here we have chosen just one of them (3/4F_{lim}) as an example to illustrate the differences between both types of projection and risk computation methods. The results are in Tables 10 and 11 and Figure 14.

When examining the results, it should be remembered that there is no uncertainty on the projected yield in cases Proj2, Proj3 and Proj4, because the projections in those cases are done with a single yield value in each year (namely the median of the yields).

Comparing Proj1 and Proj2 (different methods, same inputs), which both use the mean of the last three years for the inputs, it can be seen from the results in the tables and figure that the medians of B, SSB and Yield are similar for Proj1 and Proj2, but the confidence intervals in Proj2 are wider. The uncertainty grows as one projects further into the future, and it is very high for the SSB in 2019. As already said, we consider the projection and risk computation methodology implemented in Proj2 to be more appropriate than the one used previously (in Proj1).

Comparing Proj2 and Proj3 (same method, different inputs) shows, as expected, lower B, SSB and Yield in Proj3, as Proj3 uses the last year's weights and maturity ogive instead of the mean of the last three years, and there is a decreasing trend in these variables. Although the value of these variables in the next year is always unknown, given the marked trend observed, the next year's values are expected to be more similar to the last year than to the mean of the last three years.

Comparing Proj3 and Proj4 (same method, inputs without and with uncertainty due to interannual changes), the median of the results are almost the same, but the confidence intervals are wider for Proj4. This is a direct result of the uncertainty introduced in the inputs and it is the expected result. Given the type of uncertainty that we introduce in the mean weights and the maturity ogive, the confidence intervals of B and SSB are very wide, resulting in the 5th percentile of the SSB being very low and a 95th percentile very high. Due to the implications of the measure of the risk in the advice, how to introduce uncertainty in the inputs and the way the risk is measured need further investigation.

To summarize the results, the difference in the median of the results comes not from the method used but from the inputs used. There are big differences between taking the mean of the last three years or just the values of the last year (see Proj2 and Proj3) which is not surprising given the observed trends in the inputs. With regards to the confidence intervals of B and SSB, the difference comes from the method used, being larger in the new method proposed and especially if we use uncertainty in the inputs.

For the risks, the biggest difference comes from the method used. In the case of the methodology used until now (Proj1), the risk is calculated in a way that does not reflect the fact that the stock is managed with a (single) TAC value. We do not find this method appropriate. We believe that the method proposed here (Proj2, 3 and 4) solves this problem by calculating the risk of F exceeding F_{lim} associated with a particular catch (the median, i.e. the advised catch). This way of calculating risk is an improvement because it takes into account how advice will be implemented (single TAC value).

Comparing the different projections settings tried for the new method (Proj2, Proj3 and Proj4), a main aspect to note is that the risk of being below B_{lim}, $P(B<B_{lim})$, is higher when uncertainty in the inputs is used (Proj4). Between Proj2 and Proj3 the difference comes from a lower value in the median of the SSB in the projections, which means that the probability of being below B_{lim} increases for Proj3. But when we introduce uncertainty (from Proj3 to Proj4), while the medians are very close, the confidence interval of SSB becomes wider, and, therefore, the risk increases because we are looking to the tails of the distribution. The NAFO Precautionary Approach Framework (NAFO, 2004) gives more importance to the tails than to the median asking for a very low probability of being below B_{lim} (less than 10%), and in this case that probability is almost impossible to achieve due to the wide tails. In fact, for Proj4 the SSB in 2019 has 19% probability of being below B_{lim} although the median value of SSB is 39306 tons, much higher than B_{lim}=14 000 tons, but the lower limit of the confidence interval is just 335 tons, much smaller than B_{lim}. The same conclusions can be made for the $P(B_{2019}>B_{2015})$.

We have to be careful with these results as when we add uncertainty in the inputs the uncertainty in the results increases considerably from other Scenarios and from one year to the next with the corresponding increase in risk to be below B_{lim}, so giving advice for more than one year in this case will probably not be appropriate.

With regards to the risk of exceeding F_{lim}, all scenarios with the new method (Proj2, Proj3, Proj4) present a probability of 30% or more, being a bit higher for Proj4. In this case, the level of the risk is due that the densities of the F are spread in the right tail of the distribution, as we can see in Figure 6.

Conclusions

To solve the problems previously encountered about the calculation of risks in projections, it was **proposed** a new method (measures the risk associated with fishing a unique TAC instead of a distribution of TACs (catches) as was done in the past) to perform the 3M cod projections and compute risk. The new method solves the problems raised by the FC. We consider this procedure more reasonable since the management is done using a single TAC so the prime interest should be on the risk that exists while fishing that single TAC.

The marked decreasing trend in the biological parameters (mean weight in catch, mean weight in stock and maturity ogives) for 3M cod have created problems when providing advice for this stock. To reduce these problems, it is **suggested** in this paper to use as inputs in the projections the weights and maturity ogives of the last year instead of the usual mean of the last three years.

An additional improvement was explored to incorporate uncertainty in the projection data (mean weight in catch, mean weight in stock and maturity ogives) based on observed past interannual changes, taking into account the correlation observed between these variables. As the results from this approach show a very strong increase in uncertainty with a great impact on the estimation of the risk being below B_{lim}, it is **recommend** that this way of accounting for uncertainty must be studied more in depth before considering its implementation.

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Disclaimer

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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 2015 in tons.

Year	Estimated	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		0						66	401
2009	1161	856	87	85		22						122	1172
2010	9192	1482	374			1183	761		519			85	4404
2011	n.a.	2412	655	1609	200	2211	1063		1117		185	342	9794
2012	n.a.	2663	745	1597		2045	868		826		172	87	9003
2013	n.a.	4709	899	2323		2819	1485		1296			455	13985
2014	n.a.	5251	950	2099		3388		392	1348			862	14290
2015	n.a.	5274	905	2099		3257			1600			650	13785

[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+
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

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

Table 3.- Weight-at-age (kg) in catch.

	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

Table 4- Canadian bottom trawl survey abundance at age (thousands).

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

Table 5.- EU bottom trawl survey abundance at age (thousands).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1988	4850	78920	49050	13370	1450	210	220	60	0	0	0	0	0	0	0	0
1989	22100	12100	106400	63400	23800	1600	200	100	0	0	0	0	0	0	0	0
1990	2660	14020	5920	19970	18420	5090	390	170	90	30	0	0	0	0	0	0
1991	146100	29400	20600	2500	7800	2100	300	100	0	0	0	0	0	0	0	0
1992	75480	44280	6290	2540	410	1500	270	10	0	0	10	0	0	0	0	0
1993	4600	156100	35400	1300	1500	200	600	100	0	0	0	0	0	0	0	0
1994	3340	4550	31580	5760	150	70	10	120	0	10	0	0	0	0	0	0
1995	1640	13670	1540	4490	1070	40	30	0	20	10	0	0	0	0	0	0
1996	41	3580	7649	1020	2766	221	9	6	0	0	0	0	0	0	0	0
1997	42	171	3931	5430	442	1078	24	0	0	0	0	6	0	0	0	0
1998	27	94	106	1408	1763	87	165	0	6	0	0	0	0	0	0	0
1999	7	96	128	129	792	491	21	7	0	0	0	0	0	0	0	0
2000	186	16	343	207	100	467	180	11	17	0	0	5	0	5	0	0
2001	487	2048	15	125	81	15	146	101	6	6	6	0	0	0	0	0
2002	0	1340	609	24	68	36	28	96	33	0	6	0	0	0	0	0
2003	665	53	610	131	22	47	7	8	37	25	0	0	0	0	0	0
2004	0	3379	25	602	168	5	10	3	5	16	0	0	0	0	0	0
2005	8069	16	1118	78	708	136		17	8	8	0	0	0	0	0	0
2006	19710	3883	62	1481	86	592	115	7	0	7	14	0	7	0	0	0
2007	3910	11620	5020	21	1138	58	425	74	13	20	0	0	0	0	0	0
2008	6090	16670	12440	4530	70	940	60	230	80	0	10	0	0	0	0	0
2009	5139	7479	16150	14310	4154	26	1091	0	335	0	0	14	0	0	0	0
2010	66370	27689	8654	7633	4911	1780	8	442	46	251	26	0	0	0	0	0
2011	347674	142999	16993	6309	7739	3089	1191	0	215	0	89	0	0	0	0	0
2012	103494	128087	10942	11721	4967	4781	1630	832	24	93	30	101	0	17	0	0
2013	5525	67521	32339	4776	4185	2782	1807	963	278	40	29	32	5	0	0	0
2014	7282	2372	48564	43168	17861	6842	3447	1931	1551	600	79	54	8	0	0	0
2015	1141	12952	7250	25614	14107	21854	3434	1426	762	366	194	14	21	21	0	7

Table 6.- Weight-at-age (kg) in stock.

	1	2	3	4	5	6	7	8+
1972	0.045	0.200	0.811	0.722	0.981	1.500	1.930	2.296
1973	0.045	0.200	0.633	0.314	1.300	0.994	0.828	3.430
1974	0.045	0.200	0.657	0.805	1.769	2.829	3.983	7.701
1975	0.045	0.200	0.697	1.636	1.798	2.658	3.766	6.497
1976	0.045	0.200	0.671	1.293	4.192	5.085	5.923	6.298
1977	0.045	0.200	0.314	0.845	1.400	3.433	5.156	7.722
1978	0.045	0.200	0.374	0.600	1.102	1.582	2.658	6.351
1979	0.045	0.200	0.790	1.070	1.480	2.450	4.350	7.079
1980	0.045	0.200	0.859	1.137	1.747	2.466	3.167	4.676
1981	0.045	0.200	0.620	1.250	1.880	2.680	3.190	4.747
1982	0.045	0.200	0.760	1.340	2.450	2.870	4.680	6.146
1983	0.045	0.200	1.330	1.140	2.240	3.530	4.760	9.163
1984	0.045	0.200	0.460	1.866	3.695	3.660	6.588	6.655
1985	0.045	0.200	0.283	0.851	1.605	2.816	4.522	7.978
1986	0.045	0.200	0.411	0.784	1.631	2.836	4.317	7.389
1987	0.045	0.200	0.327	1.040	1.890	2.993	4.440	7.630
1988	0.030	0.100	0.310	0.680	1.970	3.590	5.770	6.930
1989	0.040	0.240	0.540	1.040	1.600	2.510	4.270	6.930
1990	0.040	0.170	0.340	0.850	1.500	2.430	4.080	5.640
1991	0.050	0.170	0.500	0.860	1.610	2.610	4.260	7.690
1992	0.050	0.250	0.490	1.380	1.700	2.630	3.130	6.690
1993	0.040	0.220	0.660	1.210	2.270	2.370	3.450	5.890
1994	0.060	0.210	0.590	1.320	2.260	4.030	4.030	6.720
1995	0.050	0.240	0.470	0.960	1.850	3.160	5.560	8.480
1996	0.040	0.250	0.530	0.800	1.320	2.270	4.000	5.030
1997	0.080	0.320	0.640	1.000	1.310	2.100	2.000	9.570
1998	0.070	0.360	0.750	1.190	1.660	1.990	3.100	7.400
1999	0.100	0.370	0.920	1.300	1.850	2.440	3.510	4.890
2000	0.100	0.580	0.960	1.610	1.910	2.830	3.470	5.280
2001	0.080	0.480	1.250	1.700	2.560	3.420	3.910	5.220
2002	0.065	0.420	1.120	1.430	2.470	3.590	4.860	5.310
2003	0.050	0.330	0.900	1.500	2.860	3.520	5.520	5.800
2004	0.070	0.600	1.420	2.070	3.220	5.310	5.880	7.840
2005	0.020	0.640	1.370	2.440	3.130	4.540	5.820	6.210
2006	0.090	0.700	1.060	2.490	3.570	4.690	5.760	9.550
2007	0.050	0.590	1.600	3.400	4.010	5.690	6.270	8.760
2008	0.070	0.380	1.340	2.690	3.190	5.020	6.320	7.940
2009	0.080	0.410	0.980	2.070	3.880	6.960	6.580	9.460
2010	0.060	0.380	1.090	1.680	2.960	5.380	7.620	9.140
2011	0.040	0.230	0.970	1.700	2.450	3.740	6.260	9.670
2012	0.070	0.370	0.730	1.350	1.990	2.660	4.930	7.810
2013	0.070	0.170	0.690	1.160	2.000	2.750	4.210	7.610
2014	0.050	0.170	0.350	1.060	1.620	2.540	3.850	8.440
2015	0.050	0.160	0.470	0.750	1.220	1.850	3.430	6.770

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

Table 8.- Posterior results: total biomass, SSB, recruitment (tons) and Fbar.

	B quantiles			SSB quantiles			R quantiles			F_{bar} quantiles		
Year	**50%**	**5%**	**95%**	**50%**	**5%**	**95%**	**50%**	**5%**	**95%**	**50%**	**5%**	**95%**
1972	84202	79367	90690	36966	33935	40572	17310	14230	22051	0.699	0.658	0.733
1973	49956	46393	54812	20416	17292	23851	60545	48278	79970	0.595	0.545	0.623
1974	53622	48456	61433	15181	13309	19665	119900	95628	157500	1.379	1.198	1.497
1975	68818	60682	80590	7780	6287	11989	22410	17400	30621	0.684	0.566	0.769
1976	111483	100575	126935	8758	6748	12619	9856	7865	13000	0.344	0.308	0.376
1977	84668	77983	94527	21214	17223	27543	2946	2242	4100	0.468	0.435	0.497
1978	57003	53091	62471	28735	23692	34218	19690	15780	25740	0.476	0.438	0.506
1979	50231	45964	55950	24355	21391	28739	13220	10480	17640	0.725	0.660	0.780
1980	31479	28174	36370	11643	9841	15415	7506	5667	10570	0.566	0.511	0.608
1981	34406	29825	40890	13350	9469	19071	20390	16150	27200	0.509	0.470	0.544
1982	30441	27442	34835	13340	11770	15825	20095	15830	26880	0.611	0.558	0.655
1983	40775	36262	46967	12266	10625	14685	12640	10040	16750	0.281	0.249	0.312
1984	46514	42120	52392	19814	17291	23009	14260	11250	19000	0.239	0.217	0.257
1985	39011	36084	43045	20967	19266	23008	56770	45479	74540	0.585	0.529	0.624
1986	41296	36960	47374	15662	13896	18464	116300	95680	147800	0.761	0.696	0.815
1987	54471	48566	62797	12647	11188	15364	73260	60810	92291	0.448	0.398	0.488
1988	65819	60502	73001	19363	15421	24258	15340	12350	20041	0.509	0.465	0.545
1989	106359	99485	115546	33997	27685	41702	20335	16920	25511	0.862	0.805	0.908
1990	64939	61092	70212	25455	21814	29723	25590	21640	31480	0.894	0.835	0.945
1991	44641	41262	49336	17721	14952	21174	64370	55540	77133	0.492	0.458	0.522
1992	58776	55284	63452	20972	18468	23890	58325	49860	70791	1.535	1.454	1.602
1993	46540	43296	50849	10393	8879	12590	3134	2695	3831	1.017	0.942	1.079
1994	50168	46617	55465	21671	18762	26656	4381	3268	6447	0.945	0.895	0.987
1995	22732	21378	24769	19406	18214	21226	2278	1839	2980	1.401	1.254	1.508
1996	5781	5116	6799	3473	3082	4120	141	92	229	0.676	0.562	0.768
1997	4789	4065	5942	3206	2646	4123	136	85	226	0.748	0.591	0.897
1998	3338	2451	4829	3118	2254	4596	207	145	314	0.312	0.226	0.432
1999	2431	1622	3823	2285	1489	3658	35	25	53	0.293	0.215	0.396
2000	2198	1325	3753	2034	1169	3583	343	203	586	0.186	0.127	0.266
2001	1856	1284	2729	1648	1082	2510	564	350	933	0.035	0.024	0.051
2002	2169	1599	3002	1855	1305	2675	67	41	112	0.015	0.007	0.033
2003	2402	1857	3174	2130	1610	2897	1192	766	1913	0.011	0.007	0.019
2004	3874	3116	4828	3150	2484	4079	84	60	123	0.003	0.002	0.005
2005	4283	3532	5141	3513	2880	4260	3747	2524	5977	0.007	0.004	0.011
2006	6867	5557	8706	3818	3070	4790	7741	5415	11990	0.217	0.168	0.278
2007	12763	10256	16405	5341	4122	6989	10410	7605	15120	0.031	0.024	0.042
2008	20144	16311	25600	9704	7813	12398	10135	7585	14261	0.075	0.058	0.098
2009	30640	25529	37805	18553	15323	23164	13280	10070	19000	0.044	0.035	0.054
2010	45857	39220	53990	31773	26867	38156	18940	14030	27852	0.266	0.220	0.313
2011	50694	42592	61320	31099	25347	39333	34090	23239	54950	0.290	0.216	0.376
2012	54599	44557	69238	28205	22142	38962	30360	17530	53710	0.238	0.180	0.307
2013	55315	45607	69766	36152	29721	46131	5348	2956	9686	0.273	0.214	0.333
2014	52206	42155	66861	32763	26754	42270	9664	4485	21051	0.254	0.181	0.363
2015	46174	35086	62188	28743	21497	40999	5752	2114	16580	0.157	0.103	0.266
2016	44247	29818	64914	33960	21600	53149						

Table 9.- Median of the posterior of M during the assessment with data until 2010-2015.

Data until	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Value of M	0.149	0.150	0.146	0.156	0.160	0.174

Table 10.- Results of the different projections made by $F=3/4F_{lim}$.

	Median and 90% CI			$3/4F_{lim}=0.100$					
	B			SSB			Yield		
Old projections, 3 years inputs (Proj1)									
2016	36882	54675	80277	27046	42364	65838		13931	
2017	31936	55205	88964	25348	46639	78696	5846	13359	27871
2018	35114	58592	94395	27981	48561	78914	6331	13094	24485
2019	36301	64372	110183	28250	49387	82879			
New projections, 3 years inputs (Proj2)									
2016	36882	54675	80277	27046	42364	65838		13931	
2017	31160	54130	87610	25375	46662	78681		13358	
2018	24917	56684	103171	20346	49674	94361		13184	
2019	16205	58130	118004	12757	51322	107695			
New projections, 1 years inputs (Proj3)									
2016	29801	44191	64901	21599	33930	53178		13931	
2017	21990	41042	68845	15838	32905	59031		9729	
2018	17635	45006	85750	12465	37640	76394		10215	
2019	10437	46633	99133	6584	39431	88749			
New projections, 1 years inputs with uncertainty (Proj4)									
2016	26468	45098	77610	18610	34641	63458		13931	
2017	16963	42020	86967	11016	33024	74465		9834	
2018	9924	46502	111920	5195	37942	99202		10364	
2019	2820	47078	122570	335	39306	109623			

Table 11.- Risk associated to the different projections made by $F=3/4F_{lim}$.

	Yield			$P(B_{year}<B_{lim})$				$P(F_{year}>F_{lim})$			
	2016	2017	2018	2016	2017	2018	2019	2016	2017	2018	$P(B_{2019}>B_{2015})$
Proj1, 3 years	13931	13359	13094	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.889
Proj2, 3 years	13931	13358	13184	0.000	0.000	0.020	0.060	0.520	0.300	0.340	0.840
Proj3, 1 year	13931	9729	10215	0.000	0.030	0.060	0.110	0.740	0.310	0.340	0.700
Proj4, 1 year Unc	13931	9834	10364	0.010	0.090	0.140	0.210	0.680	0.370	0.390	0.620

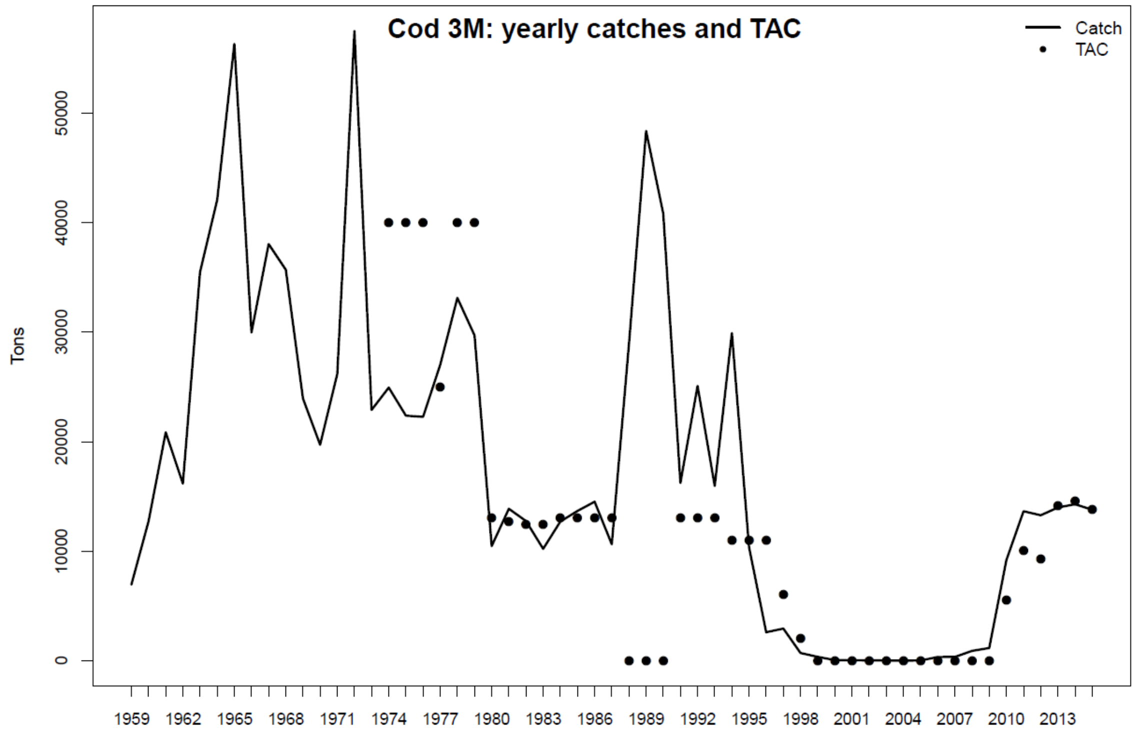

Fig. 1. 3M Cod catch and TACs

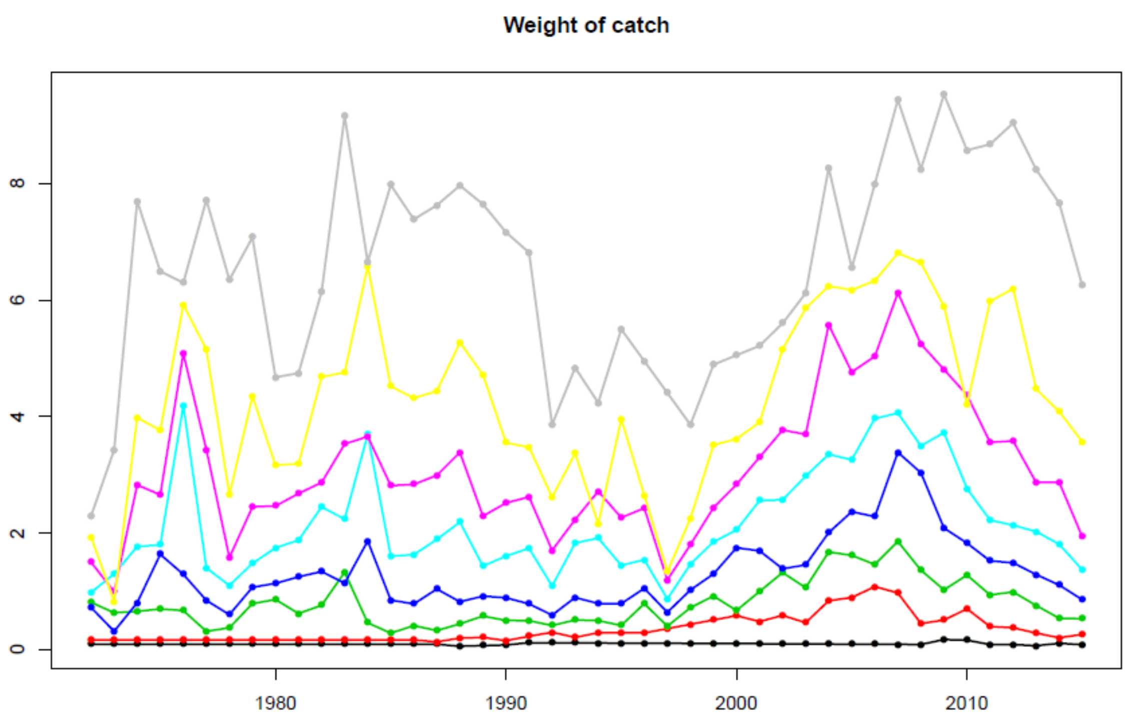

Fig. 2. Mean Weights in catch

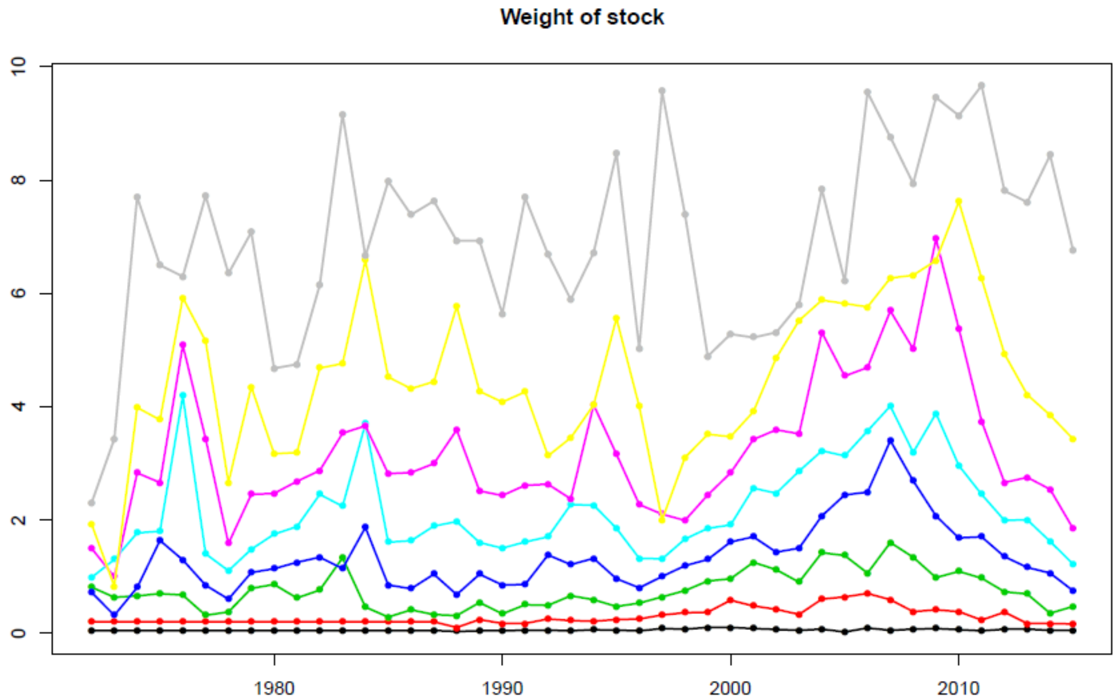

Fig. 3. Mean Weights in stock

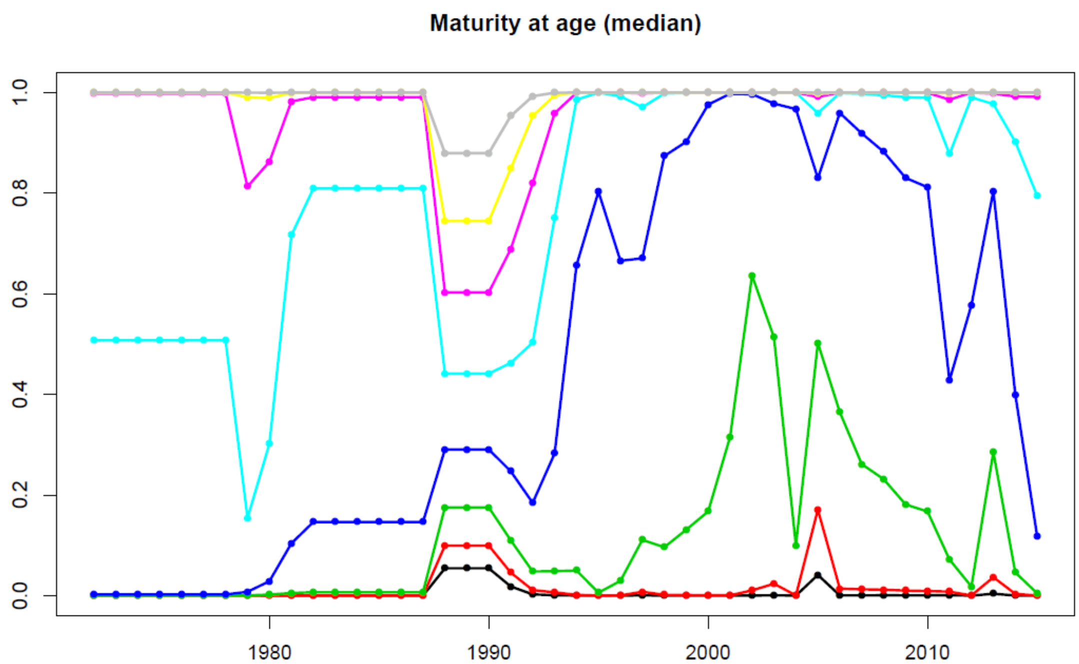

Fig. 4. Maturity ogive

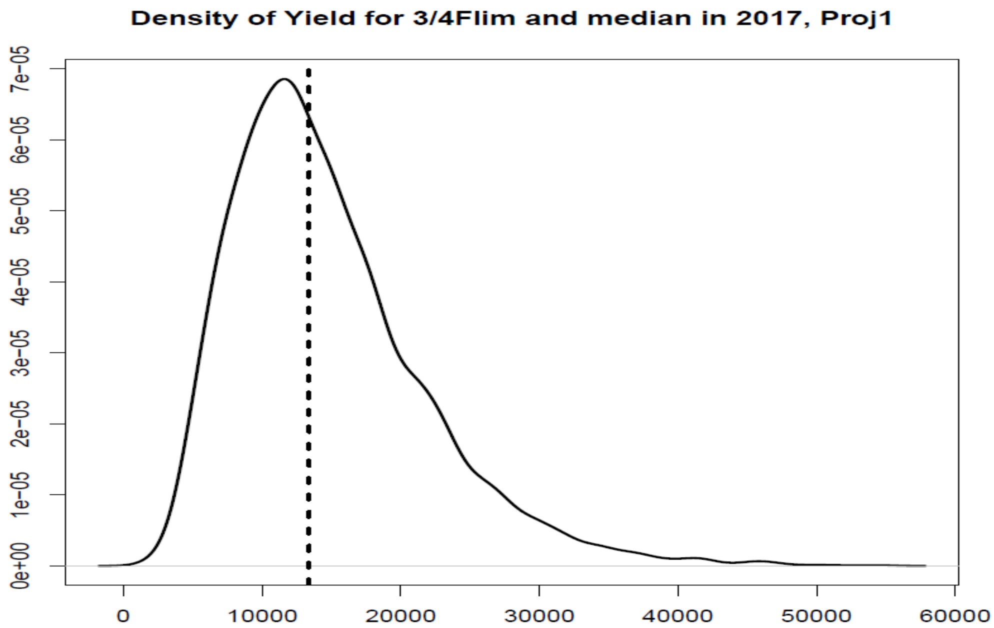

Fig. 5. Density (solid line) and median (dashed line) of the 5000 catches coming from $3/4F_{lim}$ for Proj1 during the Y+2 projected year (2017 in our case)

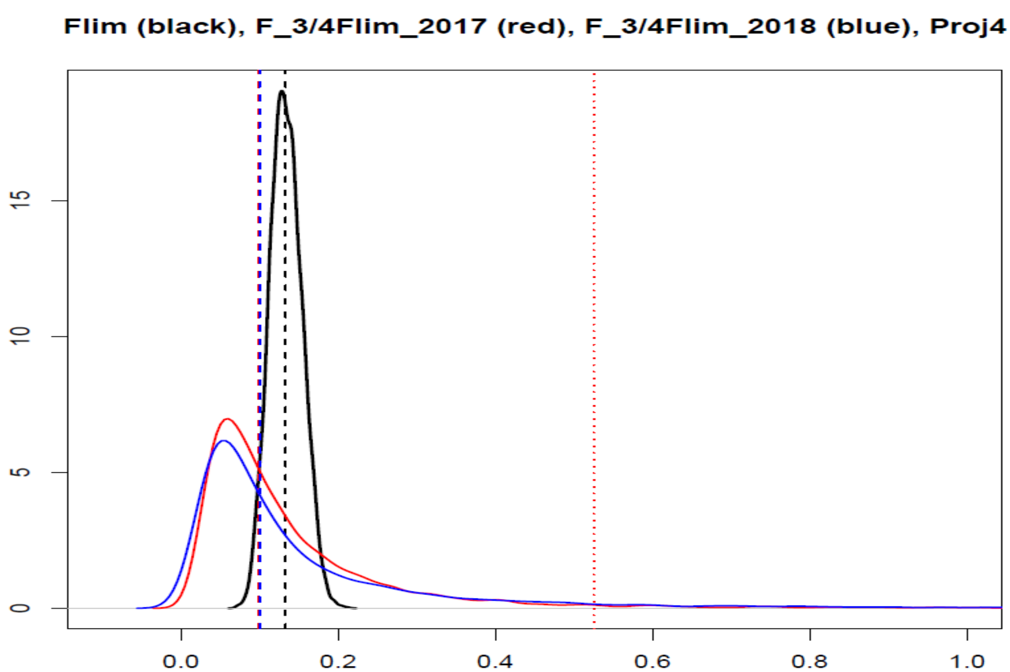

Fig. 6. Density of F_{lim} and the F in 2017 and 2018 corresponding to the Proj3 projected with $3/4F_{lim}$. The dashed lines are the medians of the distributions, and the red dotted line is the 95% confidence interval limit for the 2017. The 95% limit for 2018 is out of the graph.

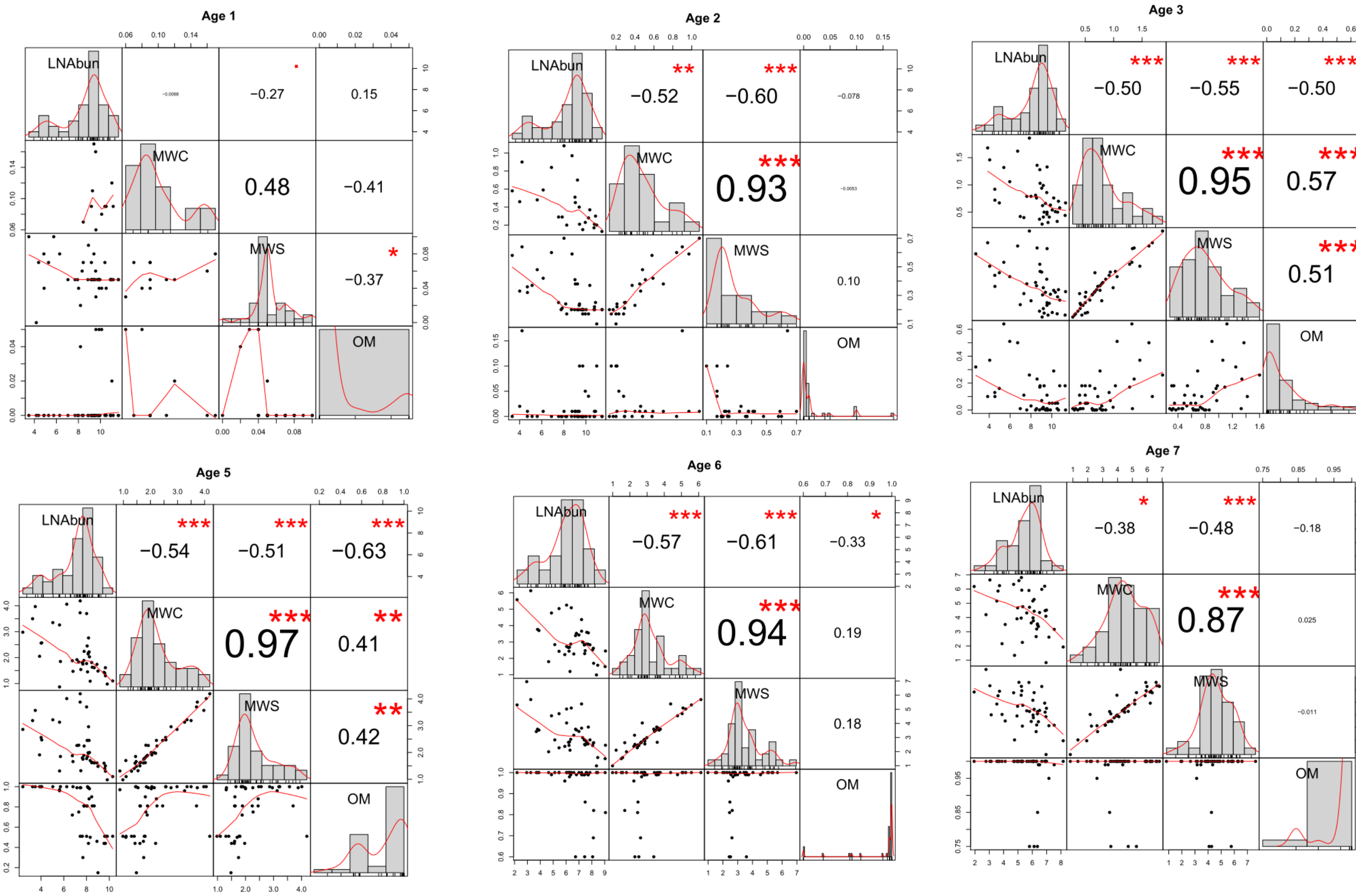

Fig.7. 3M cod correlation between Log abundance, mean weights in catches (MWC), mean weights in the stock (MWS) and maturity (MO) by age.

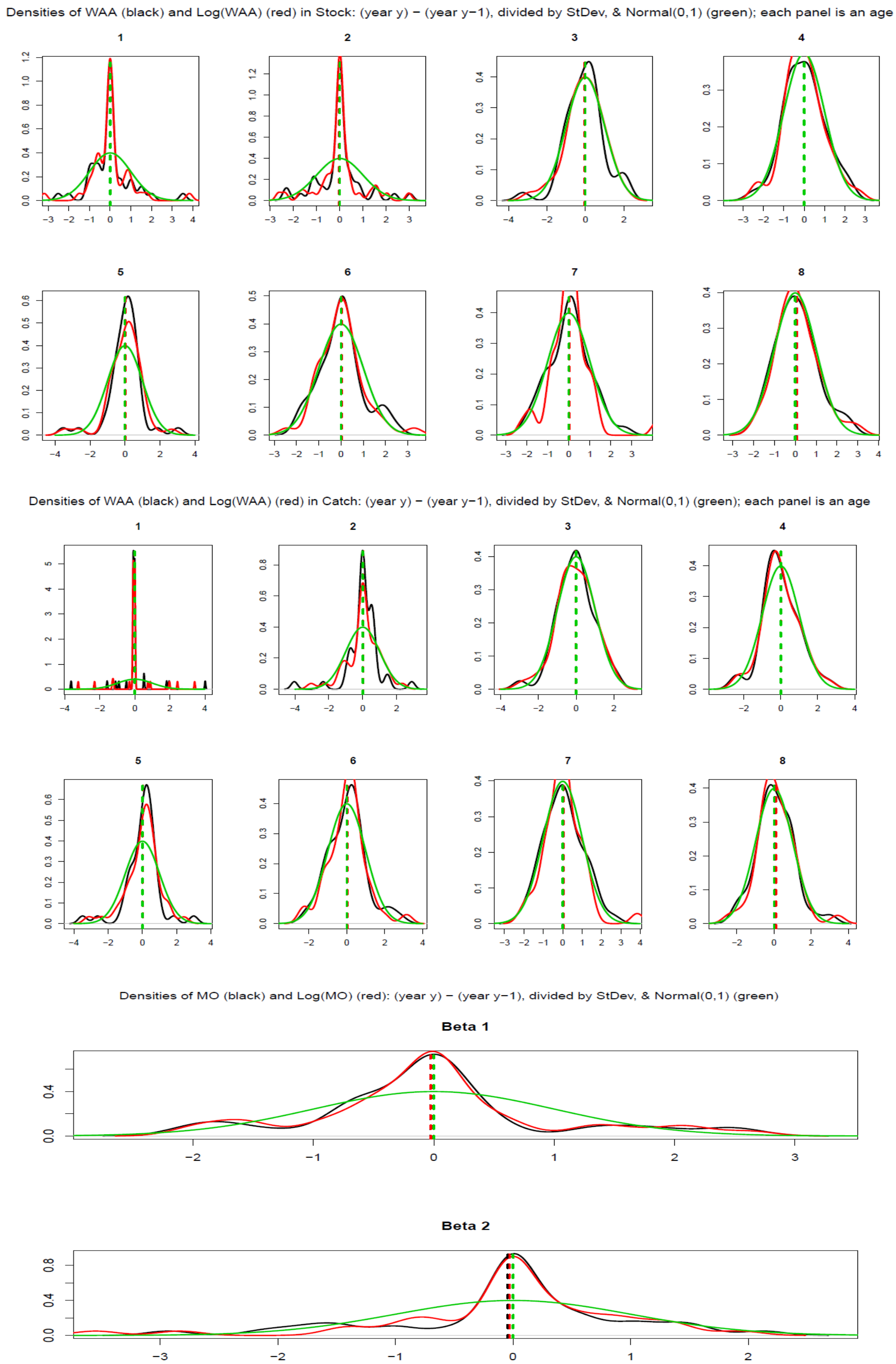

Fig. 8. Distribution of the interannual changes (1972-2015) for mean weight in catch, mean weight in stock and the parameters β_1 and β_2 of the maturity ogive

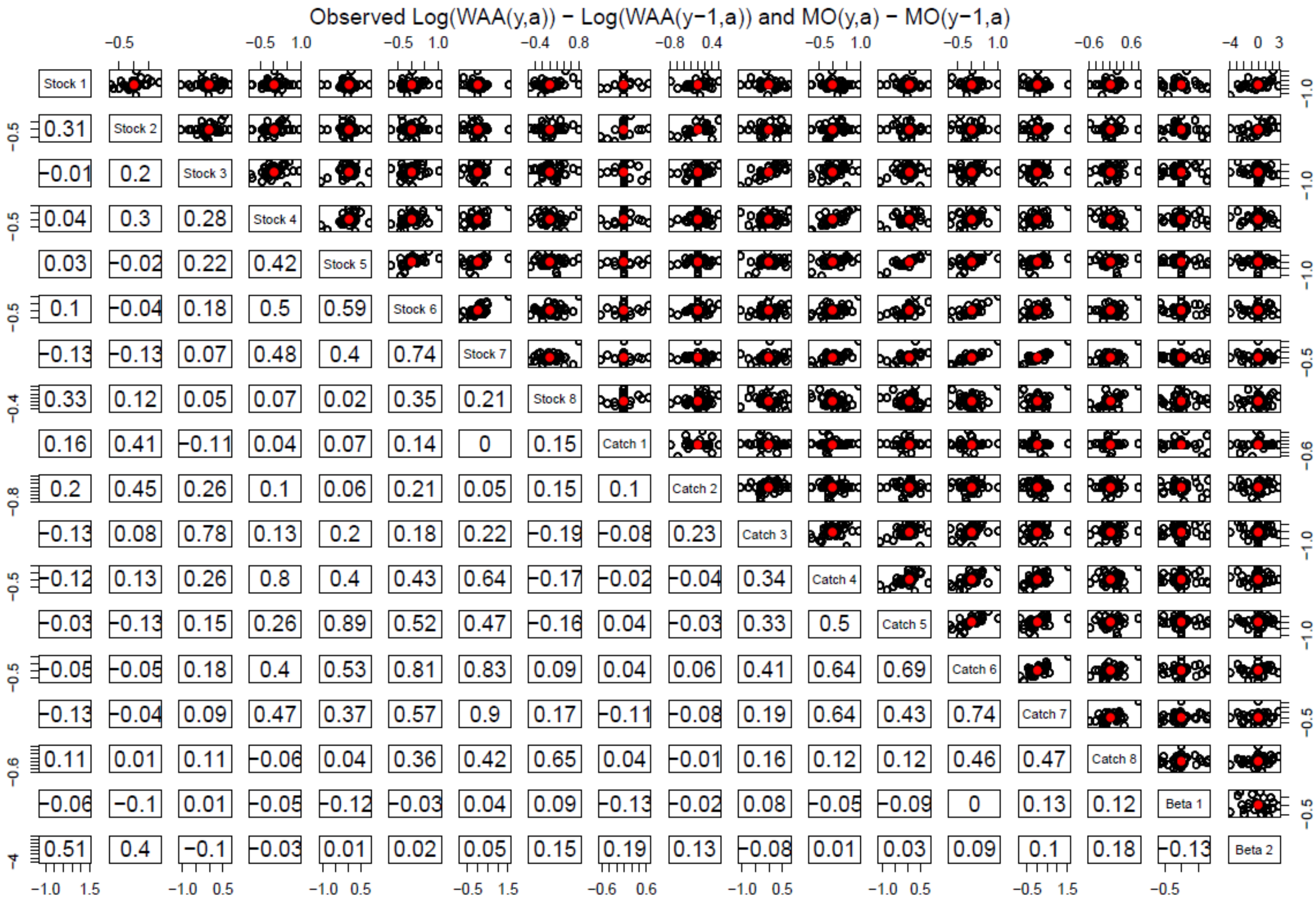

Fig. 9. 3M cod correlation between the interannual variation of Log mean weights (age) and the parameters β_1 and β_2 of the maturity ogive

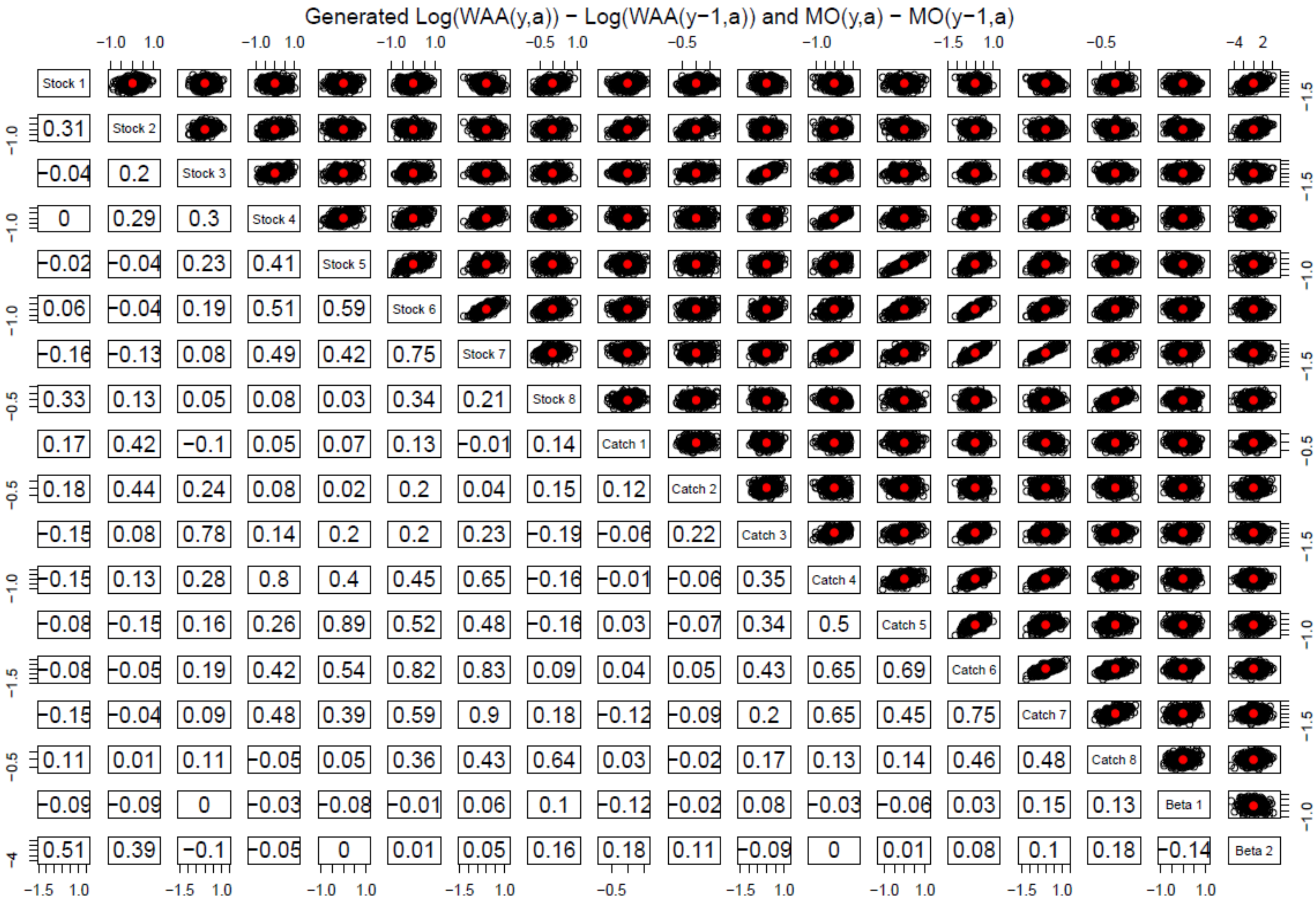

Fig. 10. 3M cod correlation between the generated interannual variation of Log mean weights (age) and the parameters β_1 and β_2 of the maturity ogive

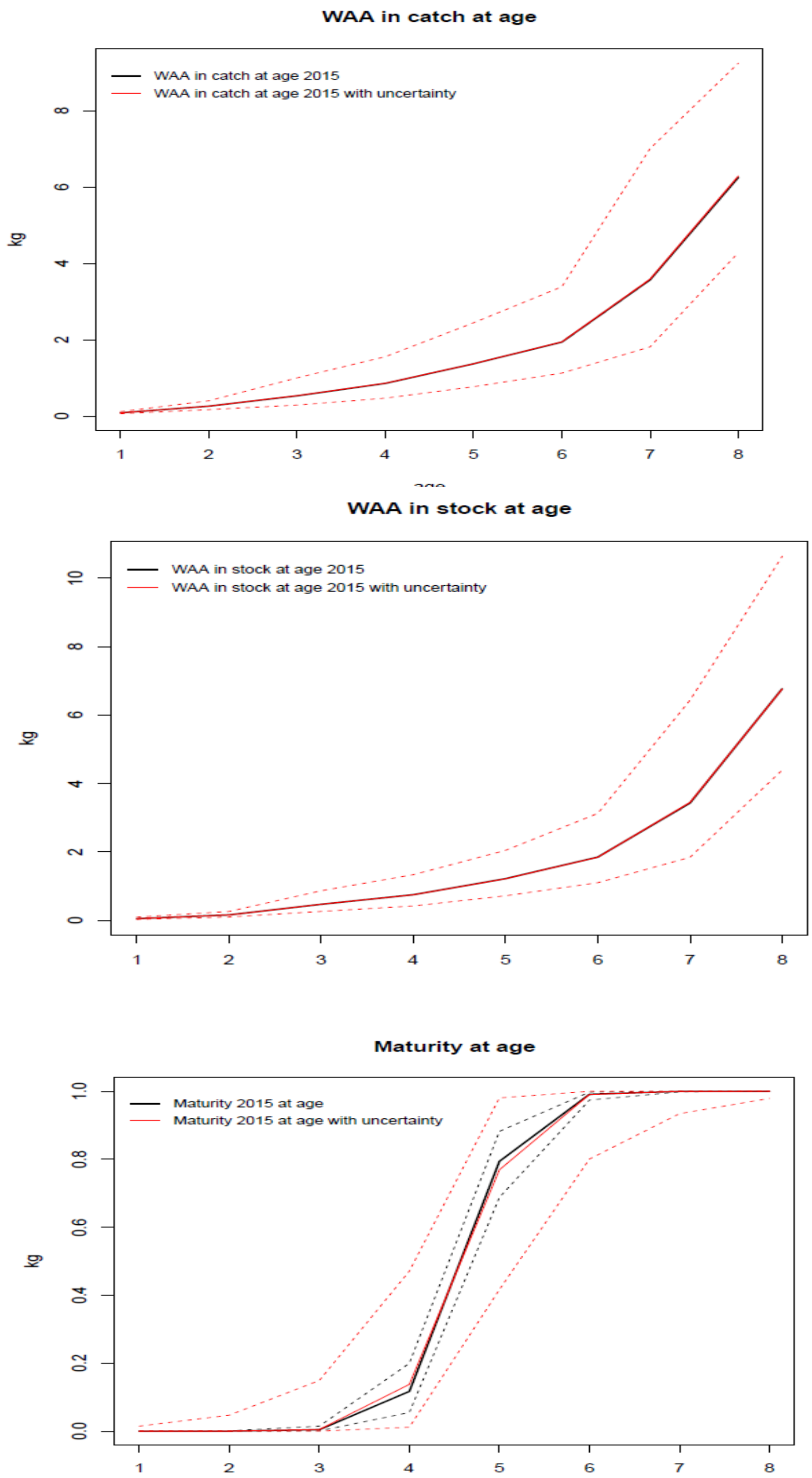

Fig. 11. Inputs of the projections with and without uncertainty

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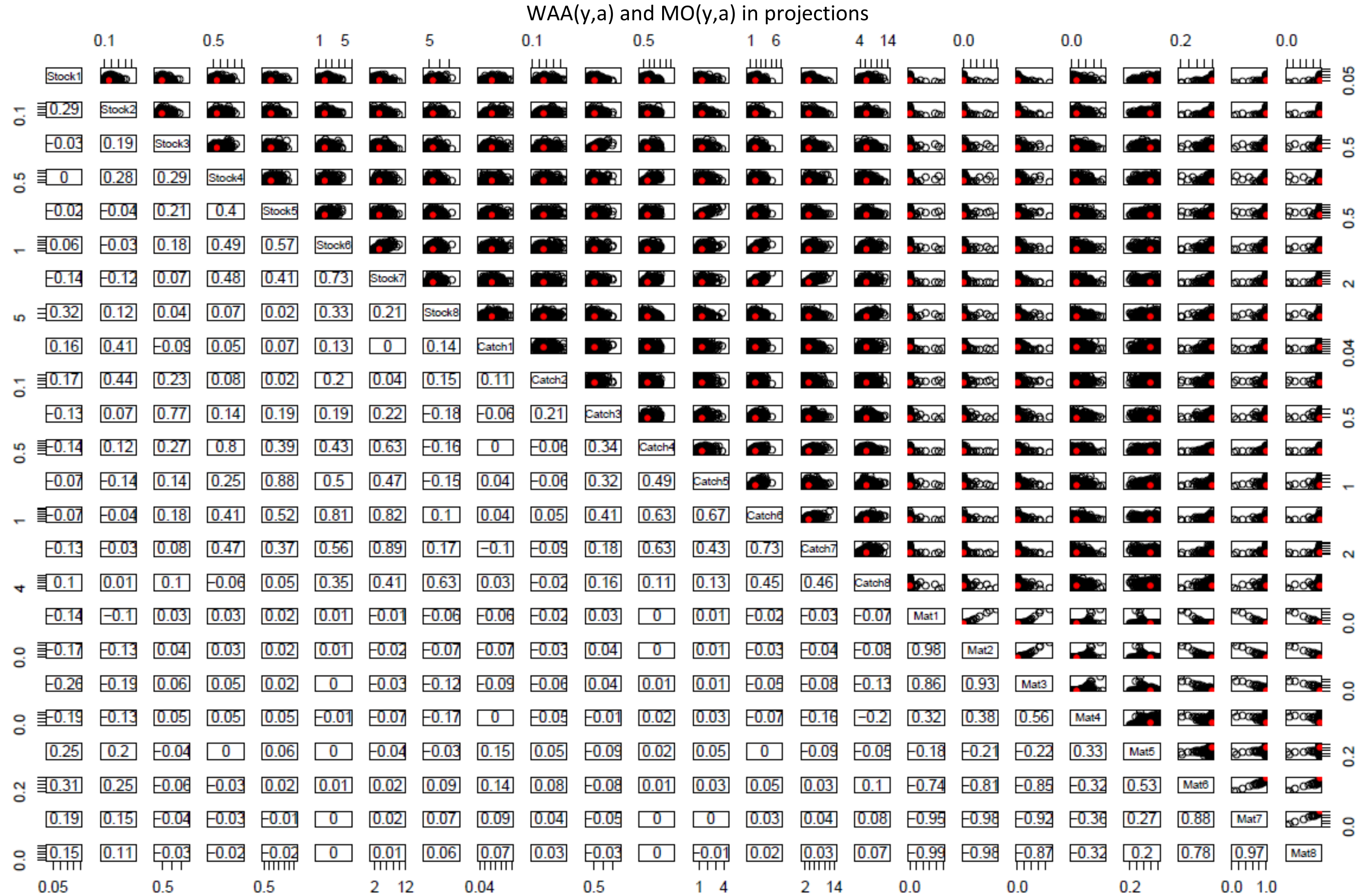

Fig. 12. 3M cod correlation between the mean weights (age) and the maturity ogive in the projections

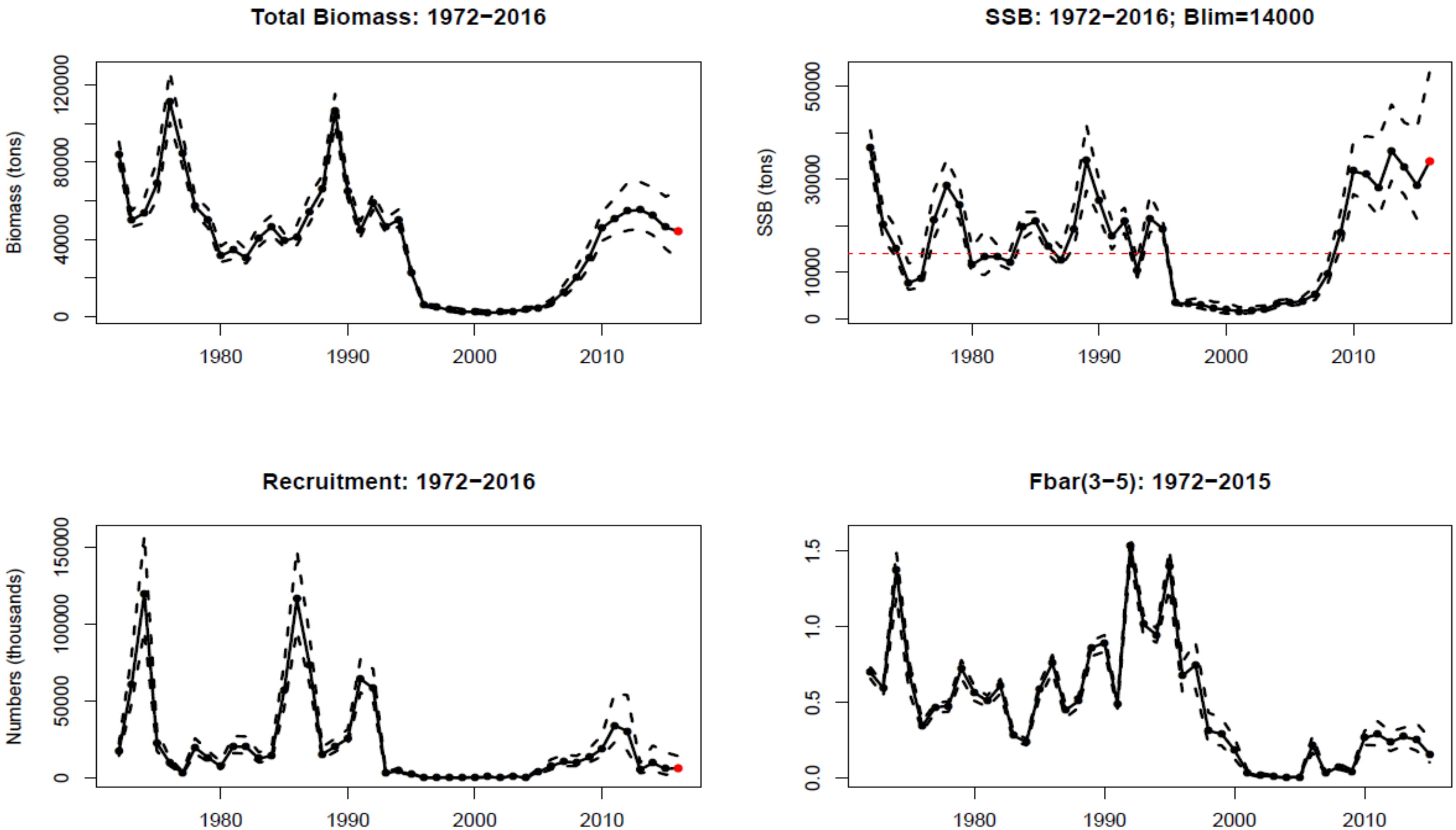

Fig. 13. Estimated trends in biomass, SSB, recruitment and F_{bar}. The solid lines represent the posterior medians and the dashed lines the limits of 90% posterior credible intervals. Red plots are the results at the beginning of 2016. Red horizontal line in the SSB graph represent B_{lim}=14000.

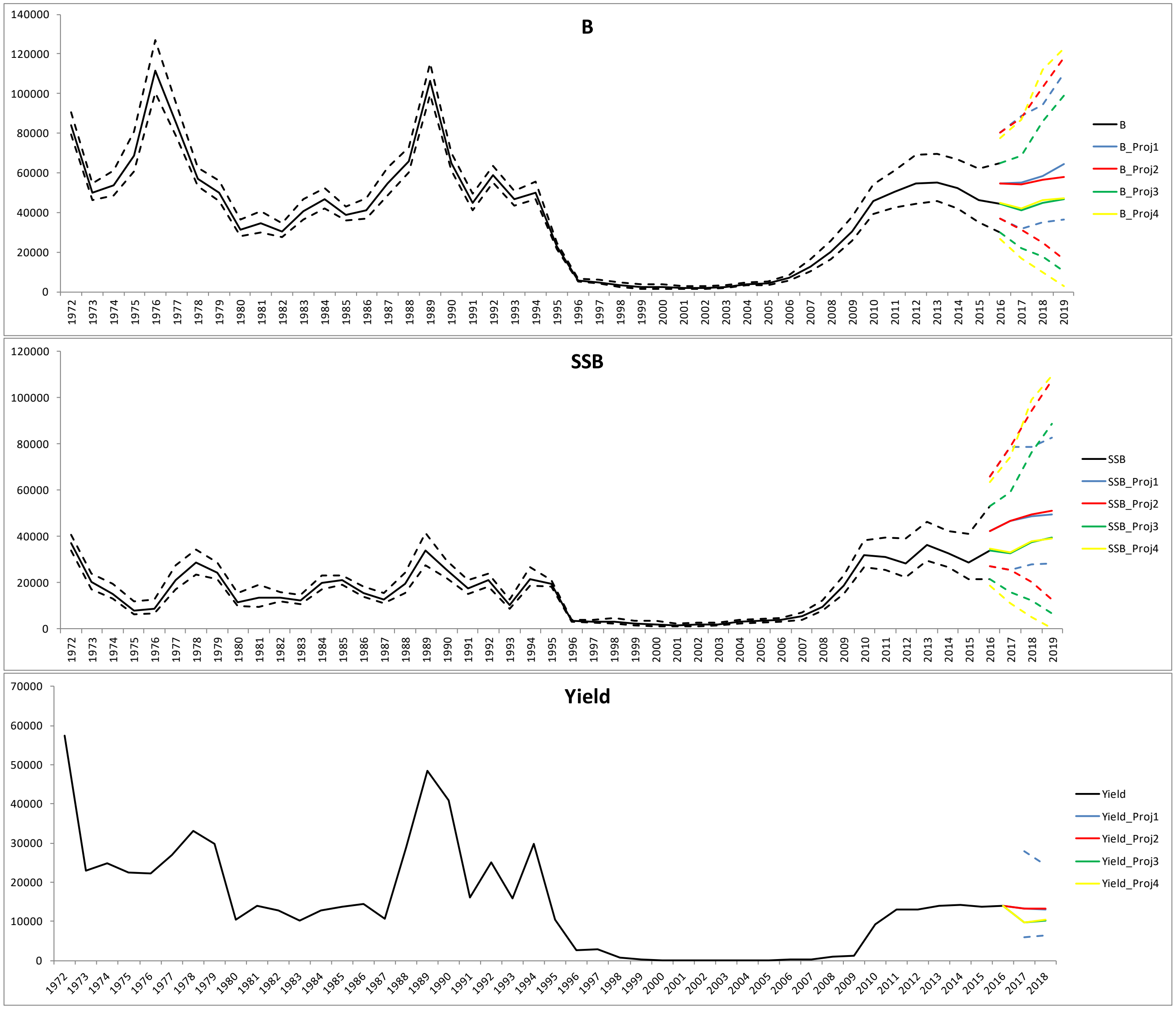

Fig. 14. Results of the four projections with F=3/4F_{lim}