Northwest Atlantic Fisheries Organization

Serial No. N6661 **NAFO SCS Doc. 17-07**

SCIENTIFIC COUNCIL MEETING – JUNE 2017

NAFO COD 3M WORKSHOP
CURRENT ASSESSMENT AND PROJECTION UNCERTAINTIES

21-23 March 2017
Centro Oceanográfico de Vigo, Beiramar venue. Vigo, Spain

Report

1. Opening

On behalf of the Specific Contract No. 03 (SC03) Support to a robust model assessment, benchmark and development of a management strategy evaluation for cod in NAFO Division 3M under the Framework Contract EASME/EMFF/2016/008 Provision of Scientific Advice for Fisheries beyond EU Waters, the NAFO 3M cod assessment Workshop was held at the Instituto Español de Oceanografia (IEO), Vigo-Beiramar, Spain, during 21st-23rd March 2017.

The Workshop was attended by the following 5 scientists from the Specific Contract No. 03 (SC03):

- Diana González Troncoso (Chairman) (IEO, Spain)
- Fernando González Costas (IEO, Spain)
- Santiago Cerviño (IEO, Spain)
- Ricardo Alpoim (IPMA, Portugal)
- Alfonso Perez Rodriguez (by video conference) (WMR, Netherlands)

The following scientists attended the Workshop as external experts:

- Carmen Fernandez (Bayesian expert)
- Carsten Hvingel (IMR, Norway)
- Mónica Mandado (IIM, Spain)

2. Appointment of Rapporteur.

Fernando González Costas was appointed as rapporteur.

3. Adoption of Agenda.

With the inclusion of the following three new points the provisional agenda (ToRs for Task 1 of SC03) was approved (Annex 1):

- Presentation of the Specific Contract No. 03 (SC03) *Support to a robust model assessment, benchmark and development of a management strategy evaluation for cod in NAFO Division 3M*.

- Proposals to be submitted to the 2017 June NAFO Scientific Council (SC) meeting.

- Recommendations from this Workshop on matters that need to be deeper studied during the benchmark process.

4. Presentation of the SC03 *Support to a robust model assessment, benchmark and development of a management strategy evaluation for cod in NAFO Division 3M*.

The Chairman presented the main tasks and schedule of the SC03.

This Workshop is part of the SC03 Task 1 (Organise a Workshop focusing on the current assessment model and the uncertainty in the projections for cod in Division 3M) and the main objective of this task is to address the shortcomings of the current NAFO 3M cod assessment model and the problems related with the risk computation in the projections raised by the NAFO Fisheries Commission in 2015. The Workshop outcomes (results and proposals) will be presented in the June NAFO Scientific Council (SC) meeting for its consideration and possible inclusion in the benchmark process.

5. Review of the currently available input data for the assessment and projections.

Task 1.1; The last 3M cod assessment was run with data until 2014. Data until 2015 will be compiled and prepared to include the most recent data in the Workshop analysis. The quality of the available new data will be analysed following NAFO SC protocols and criteria.

5.1. Data compilation.

Data until 2015 have been compiled (Total commercial catch, Catch-at-age, Weight-at-age in catch, Weight-at-age in stock, Maturity at age and age of first maturation (medians) for the 1972-2015 period; Canadian bottom trawl survey abundance at age, 1978-1985 and EU bottom trawl survey abundance at age, 1988-2015) and the latest approved 3M cod assessment (González-Troncoso, 2015) was updated with the 2015 data. The updated assessment was used, by the Workshop, as the base case assessment.

5.2. Estimation of biological parameters in the projections.

On this point the Workshop focused on the method to estimate the biological parameters used as inputs in the projection years (stock mean weight at age (MWS), catches mean weight at age (MWC) and maturity at age (MO)), because they were the ones that have created more problems when providing advice for this stock as noted by the SC (NAFO, 2015a). Normally, the value of these parameters used in the projections is the mean of the observed values in the last three years. The Workshop also studied the possibility to implement in the projections variability in these biological parameters.

It is remarkable the clear decreasing trend of the observed mean weights at age in the stock (MWS), mean weights at age in catches (MWC) and the maturity at age (MO) in the 2007 - 2015 period (Figure 1). All the observed inputs (MWS, MWC, MO) present a clear decreasing trend but it is clearer in the mean weights, where the weights in 2015 relative to 2010 are around 50% for ages 6 and younger, and around 60%-80% for ages older than 6. For example, the MWC for an individual of 6 years old in 2010 was 4.37 kg, being 1.94 kg in 2015.

These downward trends could be explained partially due to density-dependent effects. Figure 2 shows a clear negative correlation between the logarithm (LN) of abundance and the mean weights

and some maturity at age, mostly at ages 3-5. This means that at more abundance, the individuals of one age are less heavy and mature later.

This strong observed decreasing trend in the biological parameters cause problems in the projections because the values estimated for the projected years (mean of the last three years) usually are overestimated. If this trend continues in the projected period, it will lead to an overestimation of the recommended TAC for a given F. For example, at age 6, if we take the mean of years 2012, 2013 and 2014 of the MWC to predict this parameter in 2015, the difference is from 3.11 kg (three years mean) to 1.93 kg (the real observed weight).

To avoid this problem an attempt was made to estimate the biological parameters for the projections through the existing correlation between abundance and the parameters taking into account the density-dependent effects. However, although the correlation between the parameters and abundance is clearly negative, the relationship is quite noisy and the results from this attempt were not satisfactory.

Taking this into account, the Workshop **recommends** that next assessment process in 2017 makes use of the previous year's inputs instead of the usual mean of the last three years with regards to projections, to reduce the impact of this clear trend in the projections results.

5.3. Variability in biological parameters in the projections.

Taking just the last year parameters as inputs of the projections could be more accurate than using the mean of the last three years when there are clear trends. The Workshop also studied how to implement variability in the biological parameters (MWS, MWC, MO) used as inputs in the projections, incorporating the historically observed inter-annual changes.

After discussion, the Workshop decided to implement this variability considering the observed correlations between ages and among biological parameters. The proposed method to implement variability in the biological parameters will be explained in detail in a NAFO Scientific Council Research document (SCR) to be presented in the 2017 June NAFO SC meeting. The implementation of uncertainty in the inputs with this method has a great impact in the measurement of the risks, therefore the WS **proposes** that this method be revised during the Benchmark process and in the NAFO Precautionary Approach Review Working Group.

5.4. Possibility of expanding the plus group.

In recent years an increasing amount of fish has been observed in the plus group, that includes the ages of more than 8 years old (8+) (González-Costas *et al.*, 2016). The Workshop explored the possibility of expanding in the stock assessment model the current 8+ until 11+, as recommended by the NAFO SC in 2016 (NAFO, 2016).

The Workshop concluded that with the current stock assessment model (essentially a VPA) the change of the plus group is difficult to implement because it requires having the historical catch disaggregated until age 11. Furthermore, the benefits of such time consuming exercise on this issue at this moment are not clear.

The Workshop **recommends** that the benchmark process considers alternative ways of extending the plus group via:

- disaggregation of historical data or

- by using alternative stock assessment models that are capable of handling different plus group ages in the data in different years. There are assessment models such as the Statistical catch-at-age (SCAA) where this problem will have an easier solution.

5.5. Revision of the value of F_{lim}.

The NAFO Fisheries Commission in 2015 requested to Scientific Council to analyze whether the current F_{lim} value for 3M cod is currently underestimated and to revise if required the relevant fishing mortality and biomass reference points appropriately (NAFO, 2015b).

The Scientific Council decided in 2014 that $F_{30\% SPR}$ (the fishing mortality which reduces Spawner Per Recruit (SPR) to 30% of its value at F=0, so with a virgin population) is the best F_{lim} for the 3M cod stock at this moment (NAFO, 2014).

The Workshop noted that F_{lim} is sensitive to the range of years used for its calculation and the choice of the plus group.

- The range of years: There are some doubts about which range of years should be the best to estimated the inputs (MWS, MO, PR, i.e. Partial Recruitment (selectivity) pattern) needed to calculate the F_{lim}. NAFO agreed in 2014 (NAFO, 2014) to use the average of the entire time series in the assessment (starting in 1972). However, changing the range makes a big difference to the value of F_{lim}. For example, the value of F_{lim} is 40% lower when using the last three years (2013-2015) (F_{lim} = 0.076) instead of the total range (1972-2015) (F_{lim} = 0.132), and a slightly smaller reduction occurs for the projected yield under the scenario of fishing at F_{lim}.
- Choice of the plus group: Although there is no age-disaggregated catch information for ages greater than 8 years, there is available information disaggregated by age for the inputs required to estimate F_{lim} for older ages. The Workshop explored the value of F_{lim} with different choices of plus group age (11+ instead of 8+). The F_{lim} value estimated with an 8+ group is slightly higher than when estimated with 11+ group.

These issues need a deeper study in order to find the best way to estimate F_{lim}. For that, the Workshop **recommends** further investigating during the benchmark process what should be the best inputs to calculate the F_{lim}.

6. Review of the R code of the current assessment model and projections

Task 1.2; This code has been fine-tuned in recent evaluations (NAFO SCR Doc. 15/033), however an in-depth review and debug of the code is necessary.

6.1. Stock assessment code review.

The stock assessment code was reviewed and cleaned, resulting in minor changes in the code, mostly related to the way in which the inputs are structured to avoid duplications. Minor corrections were made not affecting the final results. It added new outputs in order to have a more complete set of diagnostics to help evaluate stock assessment runs.

6.2. Projections code review.

A new code has been written implementing a new projection methodology and was endorsed by the Workshop. The main idea is to use a single catch value each projected year. This is based on the idea that the main management mechanism used for this stock is a TAC, i.e. a single catch value, and managers are most likely interested in seeing the risk associated with that catch value. The method to implement the new projections methodology will be explained in detail in a SCR to be submitted in the 2017 June NAFO SC meeting.

The reviewed stock assessment code and the new projections R code will be available to the Scientific Council.

6.3. Tuning parameters in the assessment.

The 3M cod Bayesian stock assessment model uses the observed survey abundance indices for all ages 1 to 8+ to tune the assessment. The standard XSA does not use the index of the plus group age. In the stock assessment, catchability (q) is assumed to be constant over time in each age. Thus, using the plus group age for tuning implicitly means that q is assumed to be equal for all ages in the plus group (more than age 8). If this assumption is incorrect, then the true value of q for the plus group will be changing if the age structure within the plus group changes. For the moment, the Workshop **agreed** to continue to use the same approach since the differences in the final stock assessment results between using the abundance index of 8+ in the tuning or not using it are not significant.

The Workshop **recommends** that as the benchmark process will explore the possibility of expanding the plus group, this point should be explored at the same time.

6.4. Discrepancy between the calculation of the plus group in the assessment and in the projections.

At the moment, there is a potential inconsistency between the plus group abundance estimation in the assessment and in the projections. This is essentially because the stock assessment model is of a VPA type whereas the model used for projections has forward population dynamics (dynamic pool).

The current assessment model calculates $N_{y,A+}$ in the same way as XSA does, i.e. in each year y it assumes that the mortality in the plus group (A+) is the same as in the last true age (A):

$$F_{y,A+} = F_{y,A-1} \quad \text{and} \quad Z_{y,A+} = Z_{y,A-1} \qquad (1)$$

and then uses the Baranov catch equation to calculate $N_{y,A+}$ from $C_{y,A+}$, $F_{y,A+}$ and $Z_{y,A+}$ as follows:

$$N_{y,A+} = C_{y,A+} \frac{Z_{y,A+}}{F_{y,A+}\left(1-e^{-Z_{y,A+}}\right)} \qquad (2)$$

Calculating $N_{y,A+}$ from equations (1) and (2) is "correct" in the sense that it does not miss or forget about any age group. Of course, the $N_{y,A+}$ estimate resulting from equations (1) and (2) does not correspond to a dynamic pool in abundance; in other words, the estimated $N_{y,A+}$ differs from:

$$Nalt_{y,A+} = N_{y-1,A-1}e^{-Z_{y-1,A-1}} + N_{y-1,A+}e^{-Z_{y-1,A+}}$$

In order to see the differences between both calculations, it was estimated $\frac{N_{y,A+}}{Nalt_{y,A+}}$ versus year and the results plot indicates substantial differences between $N_{y,A+}$ and $Nalt_{y,A+}$ in many years (Fig. 3). Some **alternative stock assessment models** to be tested in the benchmark process (SCAA) will also have forward population dynamics and will, therefore, be fully consistent with the projection model.

6.5. Assumptions over the survey catchability.

The current stock assessment assumes that survey catchability (q) depends on population abundance for ages 1 and 2 (power model for q), i.e, that the γ parameter in equation (3) is different from 1 for ages 1 and 2:

$$CPUE_{(y,a)} = qN_{(y,a)}{}^{\gamma} \qquad (3)$$

$$LnN_{(y,a)} = \frac{1}{\gamma} LN\ CPUE_{(y,a)} - \frac{q}{\gamma}$$

High correlation between the power parameter (γ) and their corresponding q was observed (Figure 4). The Bayesian posterior distribution for the power parameters is quite different from 1 (Figure 5), particularly for age 1. This could be a reason to use these parameters.

With the available information it is not clear if this parameter should be used or not and it is **recommended** that this should be studied more in-depth during the benchmark process.

7. Potential alternatives to estimate natural mortality (M).

Task 1.3; One of the problems identified by the SC in the current assessment is the low natural mortality (M) estimated by the assessment model that seems to contradict the biology of this stock. Indirect methods will be used to estimate M based on life history parameters. The resulting M will be compared with the old M which will allow to investigate whether the actual prior used for M in the Bayesian model is still appropriate. Depending on the results the Workshop could also propose to estimate M outside the Bayesian model.

In the current assessment model M is estimated as part of the stock assessment. Preliminary investigations conducted during this Workshop **suggested** that M estimation is sensitive to the model configuration.

During the Workshop, M values estimated from a number of different published models derived from cross-species comparative analyses were presented. These models are based on fitting regressions through the relationship between estimated and measured M values and a range of life history parameters. It can be observed in Table 1 that the value of M estimated in the last approved assessment for 3M cod (M = 0.16, assumed to be the same for all ages) is one of the smallest M values. All the methods estimate M values higher than 0.2, except the Pauly method and the 2015 3M cod assessment. A general pattern of high estimated M for the younger ages was obtained from the methods that allow M to vary by size (Table 2, Figure 6), and this could be an improvement **to be studied** in the Benchmark process.

The results of the GadCap project (Perez-Rodriguez *et al.*, 2016) indicate a high variability in the 3M cod natural mortality due to predation over the period 1988-2012. The high inter-annual variability in recruitment success and the relatively low number of strong trophic interactions suggest that variability in natural mortality due to predation is probably a frequent issue in the Flemish Cap. Under these conditions, the use of a multispecies model as source of annual values of natural mortality by age, used as input for single species models could be an option.

Therefore, it may be preferable to estimate M outside the stock assessment model and, having in mind that this change could have a strong impact in other aspects, such as the Reference Points values, the Workshop **recommends** the benchmark process to further explore this issue.

8. How to implement the uncertainty in the catch projections.

Task 1.4; The Fisheries Commission in 2015 found some shortcomings in the risk estimation of the SC advice of this stock (NAFOb, 2015). Alternative new risk estimation will be studied and one will be selected to be approved by the 2017 June SC meeting and used in the next benchmark assessment. This new method will be implemented in the new R code developed by the project.

It was noted in the requests from the NAFO Fisheries Commission (FC) for clarification of scientific advice that the risks of exceeding F_{lim} for some scenarios presented in the 3M cod assessment were difficult to interpret in light of the overlap in credible intervals of the yields of the various options. This observation led to an extensive discussion within STACFIS on the methods used to calculate risk, its perception within Scientific Council, and the communication of such matters to the Fisheries Commission (NAFO, 2015c).

Three working documents were presented to the September 2015 NAFO SC meeting (NAFO, 2015c) on the issue of risk estimates associated with projected scenarios, one of which detailed the current computation done for the stock. Although there was no computation error, SC acknowledged that the risk proposed did not correspond to the expected one.

The Workshop **proposes** a new method to estimate the risk in the 3M cod projections. This new method solves the problems raised by the FC. The new method measures the risk associated with fishing the exact TAC, instead of measuring the risk associated with a distribution of TACs as was done in the past. Workshop participants found this procedure more reasonable since the management is done based on a single TAC and therefore, it is more likely that managers are interested in knowing the risk that fishing that single TAC creates.

A brief explanation of the difference between the previous projections method and the new one proposed by the Workshop follows (noting that projections start from 5000 iterations corresponding to the stock assessment). Figure 7 presents a diagram of the previous and new projections method for one iteration.

Projections as done in previous years applied an F (e.g. F_{lim} or $3/4F_{lim}$) to each of the 5000 iterations, resulting in a distribution of TACs (5000 different TACs) for each projection scenario. What the Workshop proposes is to take the median of these 5000 TACs (this is the TAC that would be used to provide advice if that projection scenario was the basis for the advice) and to apply this unique TAC in each of the 5000 iterations. This will result in 5000 different Fs corresponding to catching the unique TAC in each of the 5000 iterations. The risk of F being above F_{lim} can then be directly estimated by comparing the resulting F with F_{lim} iteration by iteration. The new method to calculate risk **will be explained in detail** in an SCR to be submitted to the 2017 June NAFO SC meeting.

9. Proposals to be submitted to the 2017 June NAFO SC meeting.

The Workshop **proposes** that the next assessment uses the last year's values of the inputs in the projections instead of the usual mean of the last three years, to reduce the impact of the trend in biological parameters.

The Workshop **proposes** a new method to estimate the risk in the 3M cod projections. The new method measures the risk associated with fishing a unique TAC instead of a distribution of TACs as was done in the past.

10. Recommendations for the 2018 Benchmark process.

The Workshop **recommends** to further investigate including variability in the biological parameters (MWS, MWC, MO) used in the projections.

The Workshop **recommends** further investigation to determine the best inputs to calculate F_{lim} during the benchmark process.

It may be preferable to estimate M outside the stock assessment model and having in mind that this change might have a strong impact on other aspects, such as the Reference Points values, the Workshop **recommends** the benchmark process to explore this issue.

The Workshop **recommends** that the benchmark process considers alternative ways of extending the plus group (via additional data disaggregation or alternative stock assessment models).

The 3M cod Bayesian assessment model includes the plus group age (8+) as part of the tuning indices. The standard XSA does not use the index of the plus group in the assessment. The Workshop **recommends** that as the benchmark process is going to explore the possibility of expanding the plus group, this point should be explored at the same time.

Currently, there is a potential inconsistency between the plus group abundance estimation in the stock assessment and the specification of the plus group abundance in the projections. Some **alternative stock assessment models** to be tested in the benchmark process will be consistent with the projection model.

Abundance based catchability is used in the current assessment for ages 1 and 2 (power model for catchability). With the available information, it is not clear if this dependence should be included and it is **recommended** that the appropriateness of the estimation of these parameters in the current model should be studied more in-depth during the benchmark process.

11. Adjournment

The Workshop was adjourned at 18:00 hours on 23 March 2017.

Conclusions

The Workshop held in Vigo was very successful in many ways.

One of them was the rich collaboration between different Institutions and External Experts which led to a productive meeting.

Another one was that the results achieved will be very helpful for the 3M cod assessment of this year and for next year's benchmark.

The results achieved for the assessment will be important during the June 2017 Scientific Council and the Workshop believes that they are going to facilitate solve the problems associated with the calculation of the risk in the projections for this stock and give a better advice to the NAFO Fisheries Commission for 2018.

The recommendations made to the benchmark process have opened the discussion and provided information in several of the issues that are going to be analyzed during it in a profitable manner. These recommendations are very complete and valuable and will facilitate the starting point deliberations in the benchmark process.

In conclusion, the results of the Workshop will be very helpful for the performance of the 3M cod assessment during 2017 and the benchmark process during 2018.

Acknowledgements

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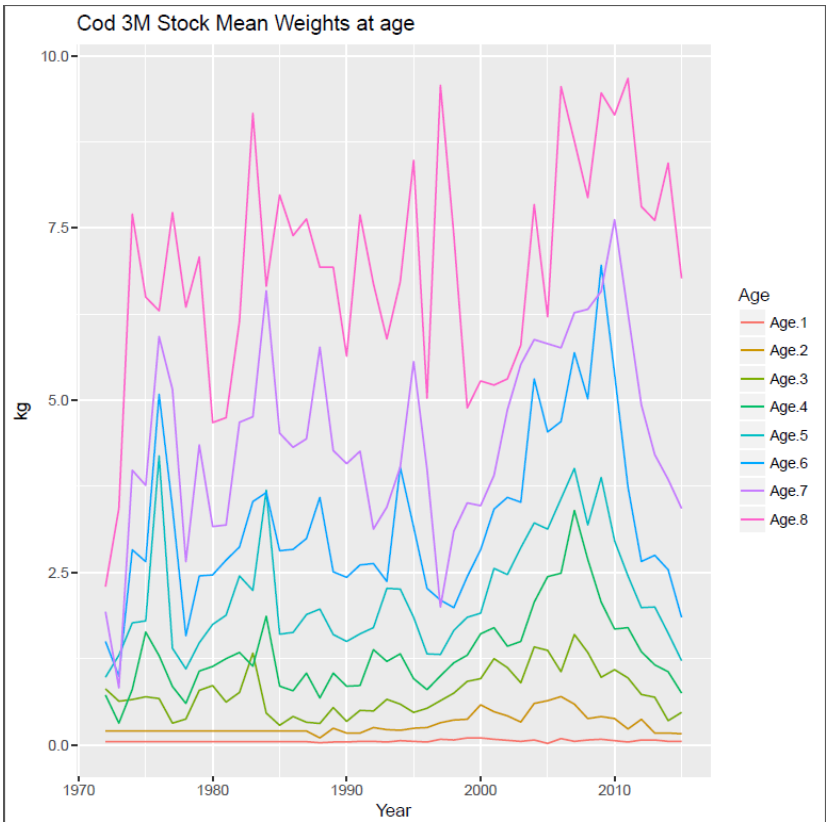
LIST OF TABLES AND FIGURES

Table 1-. M values estimated with age-independent methods (see References).

Method	**M**
Hewitt and Hoenig (2005)	0.25
Hoenig (1983)	0.25
Pauly (1980) length	0.11
Pauly (1980) weight	0.14
Jensen (1996)	0.42

Table 2-. M values by age estimated with the size-dependent methods (see References).

Age	1	2	3	4	5	6	7
M (Gislason)	2.19	0.99	0.56	0.41	0.32	0.25	0.20
M(Charnov)	2.33	1.11	0.66	0.48	0.39	0.31	0.25
M(Peterson and Wroblewski)	0.70	0.48	0.37	0.32	0.29	0.26	0.23
M(Lorenzen General)	0.94	0.61	0.45	0.38	0.33	0.29	0.26
M(Lorenzen Fish)	1.08	0.69	0.50	0.42	0.36	0.32	0.27
M (Chen&Wata)	2.06	0.67	0.39	0.26	0.19	0.15	0.16
2015 assessment	0.16	0.16	0.16	0.16	0.16	0.16	0.16
M (Gaget)	0.75	0.62	0.18				


Cod 3M Stock Mean Weights at age
10.0
7.5
5.0
2.5
0.0
kg
1970
1980
1990
2000
2010
Year
Age
Age.1
Age.2
Age.3
Age.4
Age.5
Age.6
Age.7
Age.8

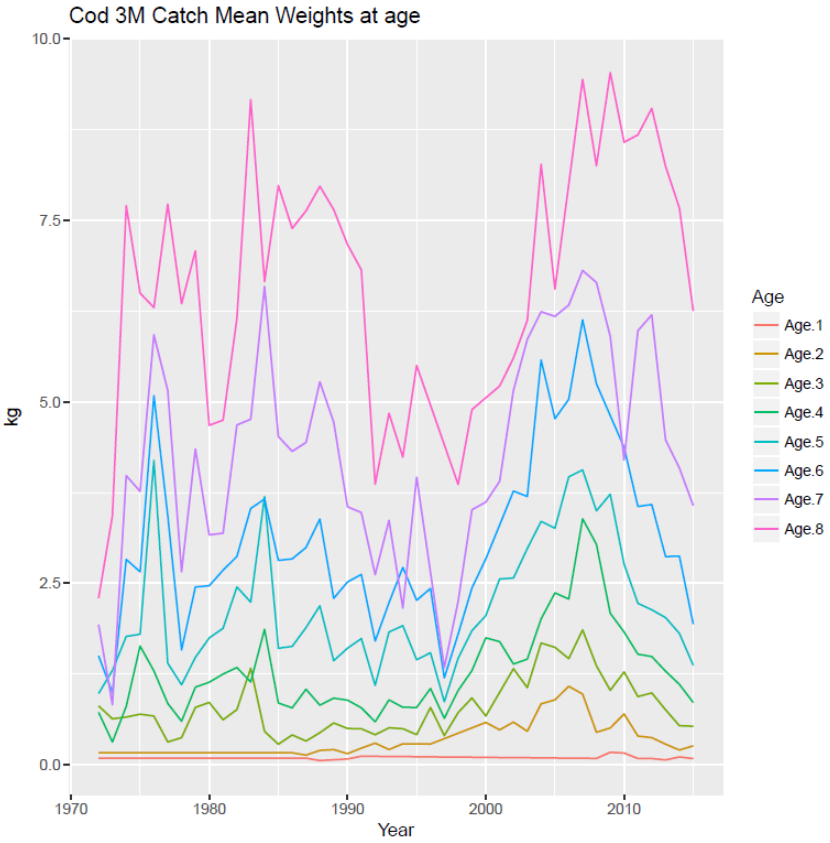
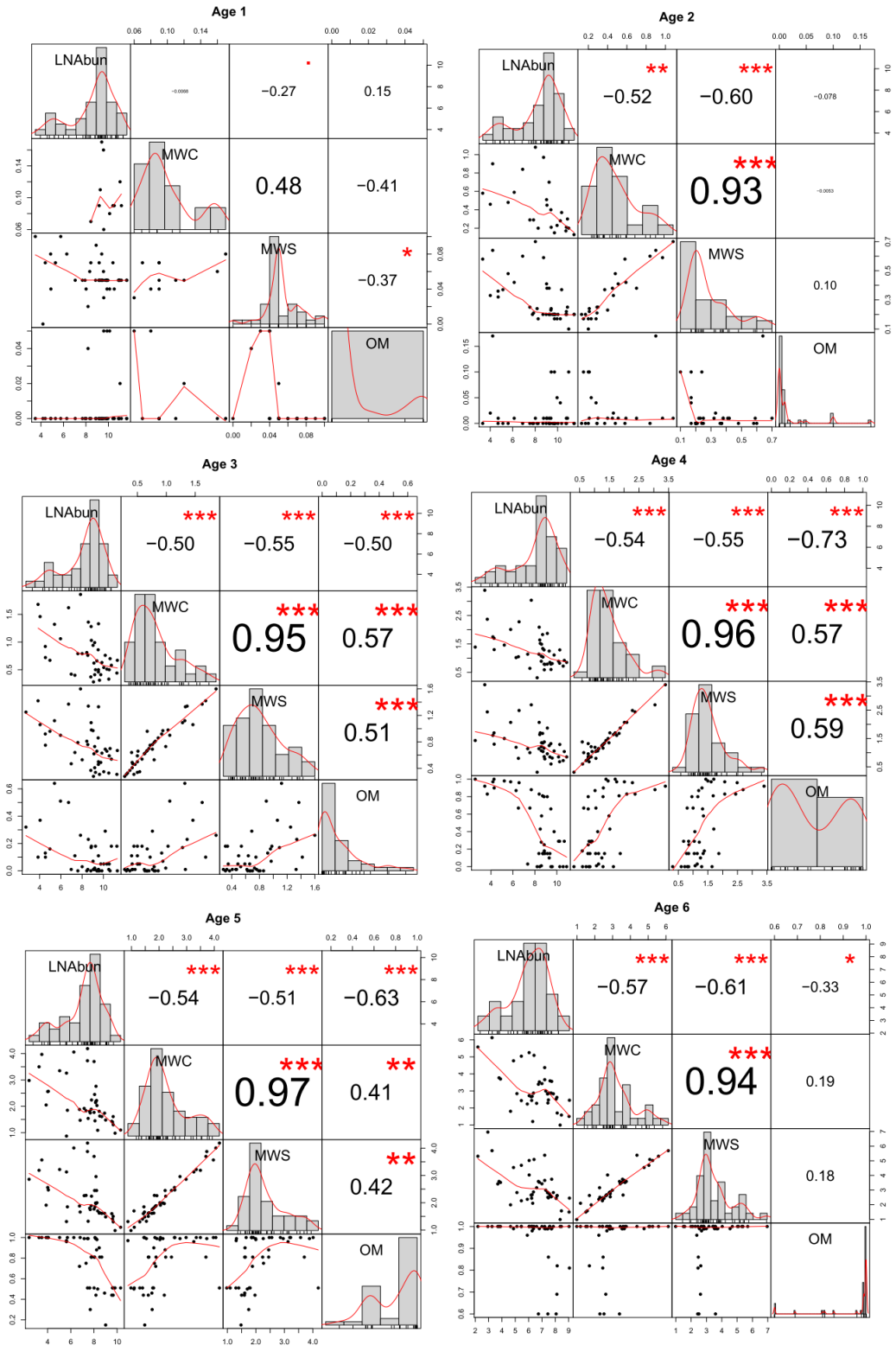

Cod 3M Catch Mean Weights at age
10.0
7.5
5.0
2.5
0.0
kg
1970
1980
1990
2000
2010
Year
Age
Age.1
Age.2
Age.3
Age.4
Age.5
Age.6
Age.7
Age.8

Fig. 1. Cod 3M mean weights (kg) at age in the stock, mean weights (kg) at age in catches and the maturity at age by year.


Age 1
LNAbun
MWC
MWS
OM
−0.27
0.15
0.48
−0.41
−0.37
*
Age 2
LNAbun
MWC
MWS
OM
**
***
−0.52
−0.60
−0.078
***
0.93
0.10
Age 3
LNAbun
MWC
MWS
OM
***
−0.50
−0.55
−0.50
0.95
0.57
0.51
Age 4
LNAbun
MWC
MWS
OM
***
−0.54
−0.55
−0.73
0.96
0.57
0.59
Age 5
LNAbun
MWC
MWS
OM
***
−0.54
−0.51
−0.63
0.97
0.41
**
0.42
Age 6
LNAbun
MWC
MWS
OM
***
−0.57
−0.61
*
−0.33
0.94
0.19
0.18

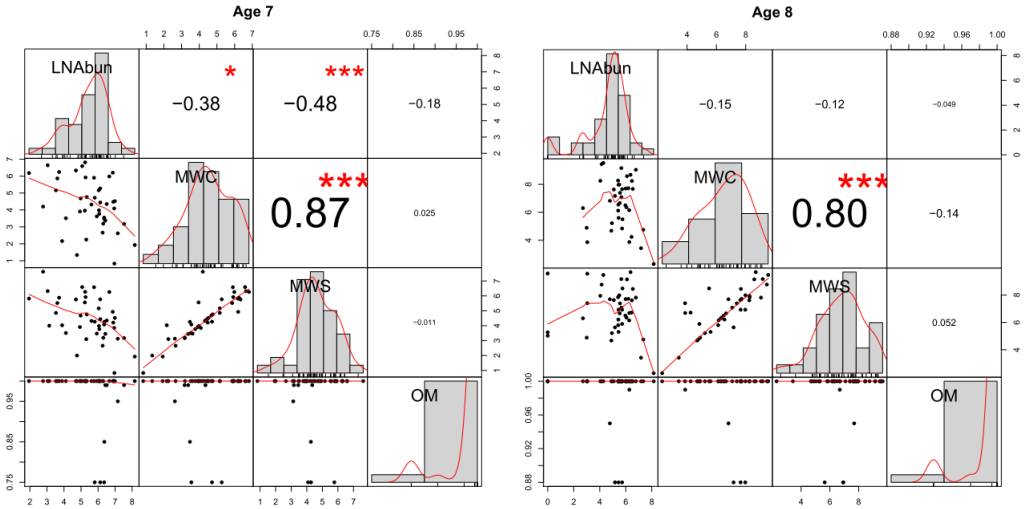


Fig. 2. Cod 3M correlation between LN abundance, mean weights in catches (MWC), mean weights in the stock (MWS) and maturity (MO) by age.

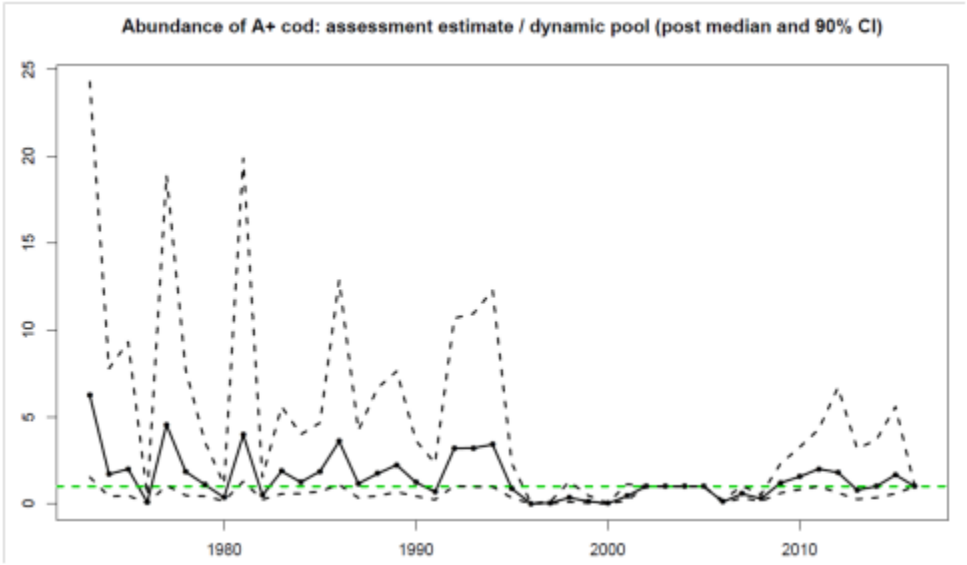


Fig. 3. Ratio of the estimated assessment eight plus group abundance and the alternative dynamic pool estimation (black line) with their 90% confidence interval (dotted black line). Dotted green line is ratio=1.

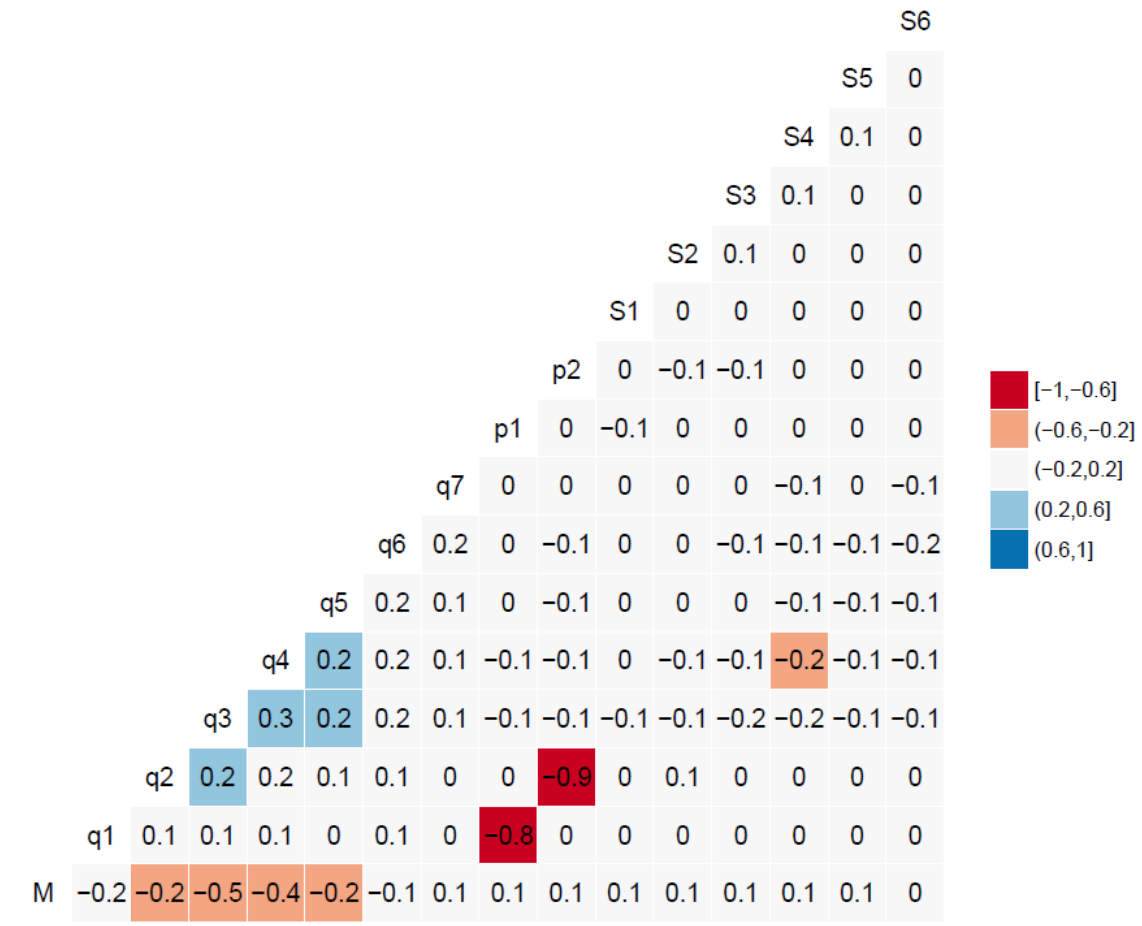


Fig. 4. Cod 3M correlation between natural mortality (M), catchability at age (q1-q7), power parameters relating *q* with the abundance in ages 1 and 2 (p1-p2), and survivors of ages (S1-S6) in the final assessment year.

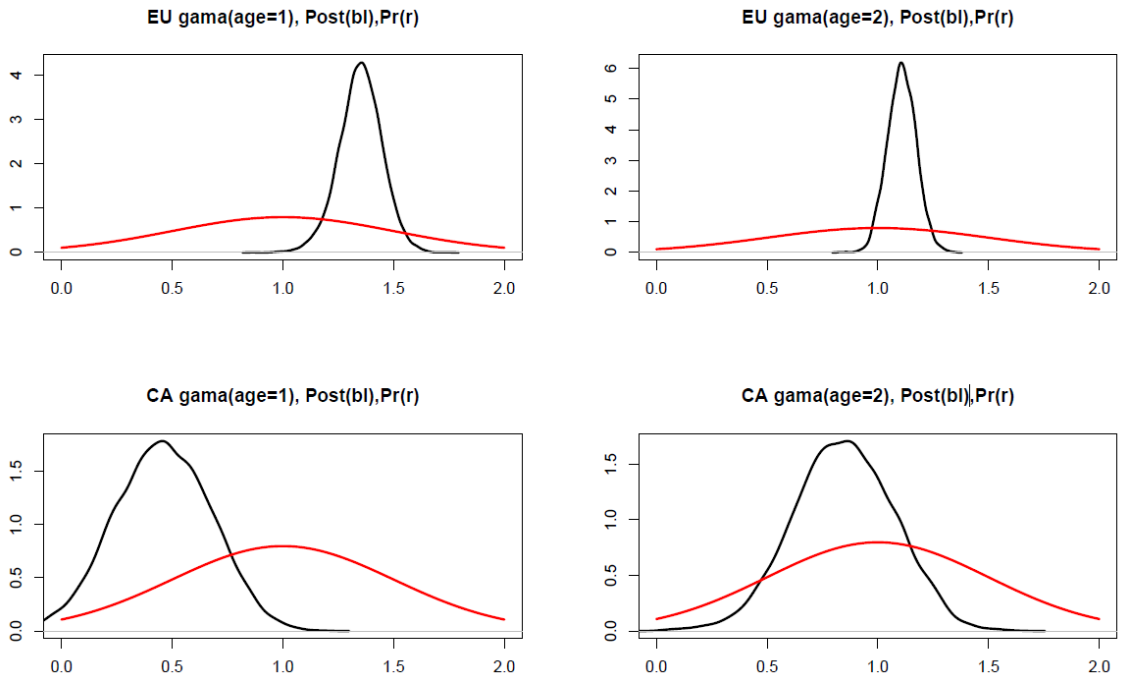


Fig. 5. Power parameters gama (γ) relating catchability (q) with the abundance for ages 1 and 2 Bayesian posterior distribution. EU is Flemish Cap survey and CA is the Canadian survey used in the Cod 3M assessment as tuning. Post=Posterior Bayesian distribution; Pr=Prior Bayesian Distribution; (bl)=Black and (r)=Red.

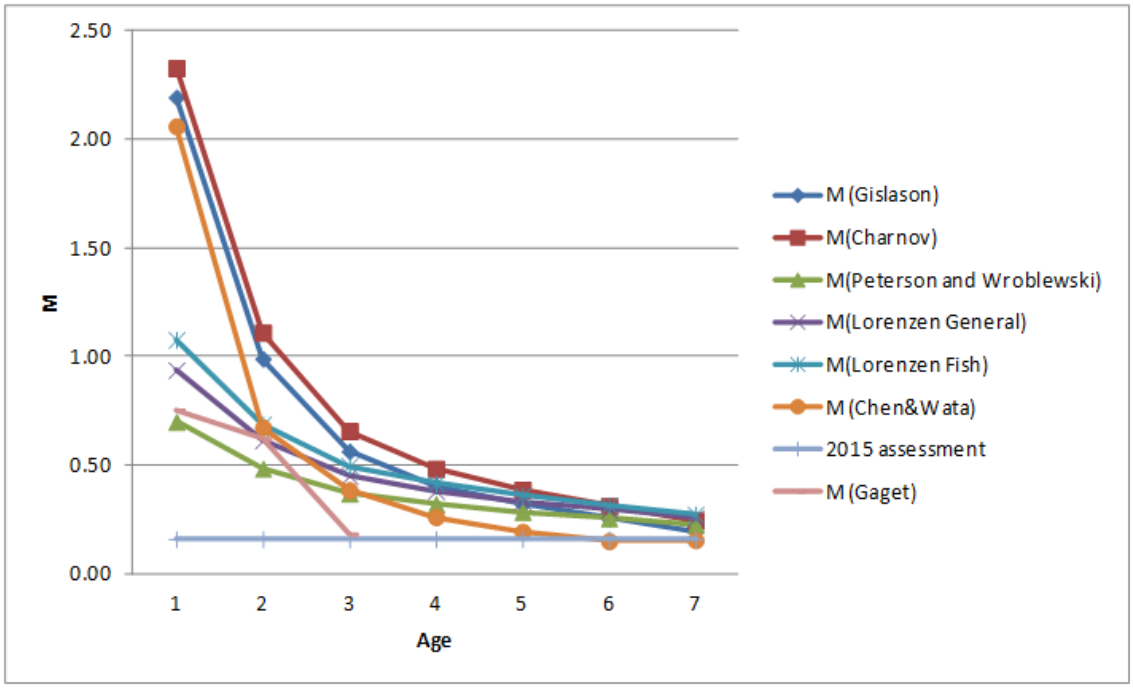


Fig. 6. M values by age estimated with the size-dependent methods.

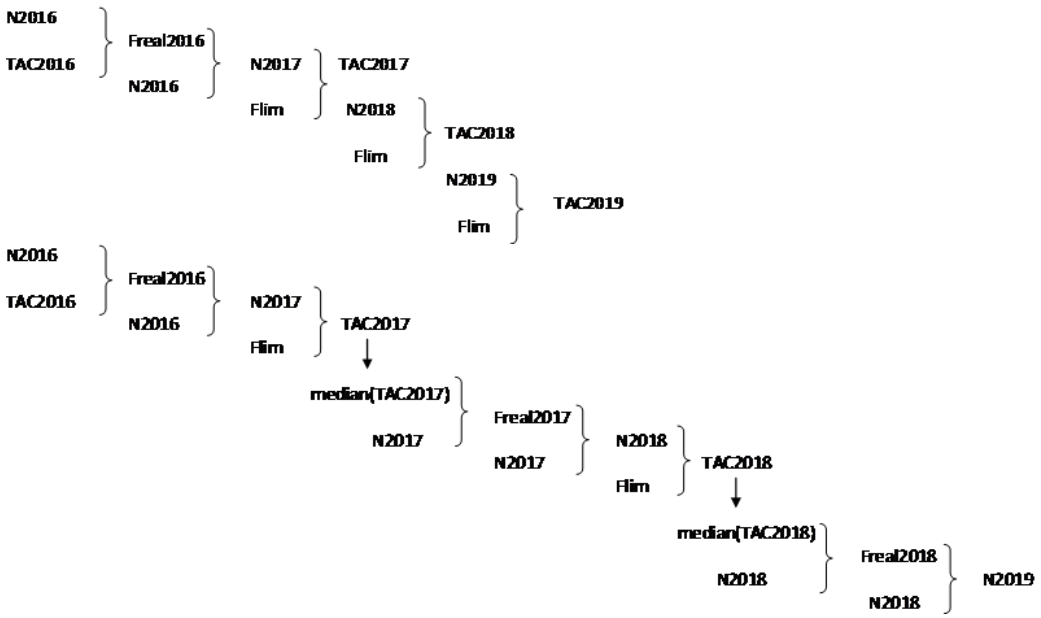


Fig. 7. Diagram of the previous (above) and new (below) projections method for one iteration.

Annex 1

3M COD WORKSHOP: CURRENT ASSESSMENT AND PROJECTION UNCERTAINTIES

21-23 March 2017
Centro Oceanográfico de Vigo, Beiramar venue. Vigo, Spain

Agenda

1. **Opening**
2. **Appointment of Rapporteur**
3. **Adoption of Agenda**
4. **Presentation of the Specific Contract No. 03 (SC3) "Support to a robust model assessment, benchmark and development of a management strategy evaluation for cod in NAFO Division 3M".**
5. **Review of the currently available input data for the assessment with the aim to improve previous assessment**. *The last 3M cod assessment was run with data until 2014. Data until 2015 will be compiled and prepared to include the most recent data in the workshop analysis. The quality of the available new data will be analysed following NAFO SC protocols and criteria.*
6. **Review of the R code of the current assessment model.** *This code has been fine-tuned in recent evaluations (NAFO SCR Doc. 15/033), however an in-depth review and debug of the code is necessary.*
7. **Potential alternatives to estimate natural mortality (M).** *One of the problems identified by the SC of the current assessment is the low natural mortality (M) estimated by the assessment model that seems to contradict with the biology of this stock. Indirect methods will be used to estimate M based on life history parameters. The resulting M will be compared with the old M which will allow to investigate whether the actual prior used for M in the Bayesian model is still appropriate. Depending on the results the WS could also propose to estimate M outside the Bayesian model.*
8. **How to implement the uncertainty in the catch projections**. *The FC in 2015 found some shortcomings in the risk estimation of the SC advice of this stock (NAFO/FC Doc. 15/23). Alternative new risk estimation will be studied and one will be selected to be approved by the 2017 June SC meeting and used in the next benchmark assessment. This new method will be implemented in the new R code developed by the project.*
9. **Proposals to be submitted to the 2017 June NAFO SC meeting.**
10. **Recommendations from this Workshop on matters that need to be deeper studied during the benchmark process.**