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Exploratory assessment of the cod 3M stock using SAM

by

Thomas Brunel

Wageningen Marine Research
P.O. Box 68, 1970 AB Ijmuiden, The Netherlands
thomas.brunel@wur.nl

Abstract

In the context of the benchmark for the cod 3M stock and funded by a EU specific contract (EASME/EMFF/2016/008), a series of runs with state space assessment model (SAM) (Nielsen, A and Berg, 2014) were presented, in order to provide a comparison with the runs from other assessment models (Bayesian XSA and Statistical Catch at Age, SCAA) presented at the meeting, and to explore alternative configurations. The model was also run using a time-varying/age-specific natural mortality estimated by the multi-species model Gadget.

The series of runs are presented in table 1, with an explanation of the corresponding model configuration and goodness of fit criteria. The first runs consisted in applying the 2 preferred configurations from the SCAA model (named R19 and R15 respectively). Then different options for coupling/decoupling by age groups various parameters (observation variances, catchabilities) were investigated. Finally an unstructured correlation matrix was added for the observation errors for the catches and the survey.

Preferred SCAA configurations

The parameters estimated for the run R19 and R15 are presented on figure 1. The difference between the two runs is in the grouping of catches and survey observation standard deviations (stdev) per age-classes. The configuration R19 estimates observation stdev for all ages. For the catches, the stdev tended to decrease from age 1 to age 7, and increased again for age 8. However, the stdev for age 6 did not comply with this pattern, with a very high estimate. There was also a similar U shape pattern for the stdev of the survey, with higher values for ages 1, 2 and 8, and the lowest value for age 5, but the difference was less pronounced than for the catches stdev, and confidence intervals overlaped for most ages. The model configuration R19 had a low process error, large variability in recruitment, and smoother fishing mortality random walks for age 1 than for older ages. The catchability model exponent was significantly larger than 1, implying that the availability of age 1 fish for the survey is higher for larger cohorts. Survey catchability at age 2 was similar to the estimate for older ages 3-8 (the catchability for age 1 cannot be compared as the model has an exponent on abundance only for this age). In general observation standard deviations were high (>0.5), meaning that the model considered both sources of data as noisy.

In comparison, model configuration R15 indicated a clear difference between observation stdev for catches at age 1-2, 3-6 and 7-8. This was not the case of survey observation stdev for ages 1 and 2-8 which were estimated at similar values. Process error stdev was markedly larger for R15. Other parameters were similar between R15 and R19. Both models had a similar AIC value, indicating that there is no clear reason to prefer one model configuration over the other.

The estimated stock trajectories from SAM and from the SCAA were very similar for the configuration R19 (figure 2). The SAM run with configuration R15 also gave a similar trend as the two R19 runs (expect small differences in the recent years), but the SCAA R15 run appeared to estimate a lower SSB.

Configuration for the standard deviations of the observation errors

The model R19 estimated observation stdev for all ages. The patterns observed (e.g. absence of difference in stdev estimates for the different ages in the EU survey) suggests that the model can be improved by grouping parameters for some of the age-class. Alternative configuration for the grouping of the age-classes for the observation stdev for the catches and survey were then explored.

First, estimating a single parameter for all ages for the survey (mod2) resulted in a lower AIC , and a likelihood ratio test comparing mod2 and R15 indicated that the improvement in the model likelihood related to the estimating 2 stdev instead of one was not significant. Alternatively, the model was run with a different grouping as in model R15 (mod2.2 : ages1-2 and ages 3-8). This did not result in a significant model improvement compared to mod 2.

SAM was also run grouping all age classes for both stdev on catches and on the survey (mod 3). Model AIC increased and a likelihood ratio indicated that mod2 performed better than mod3.

Finally (not shown), there was no difference in the estimated SSB, Fbar and recruitment between model R15 and mod2, and only a minor difference with the model mod3.

Despite biological reasons to suspect that the survey data is noisier for younger ages, these exploratory runs suggested that there is no support for estimating age-specific observation standard deviations for the different ages for the survey. A distinction between age groups for the catches seems however more appropriate than a single parameter.

Configuration for the survey catchability

SAM was run with a configuration estimating one catchability parameter per age-class (mod4). This resulted in large decrease in the AIC compared to mod 2. The age-specific estimates suggested that the catchability at age 2 was not different from subsequent ages (whereas it is treated as a separate parameter in mod2, R15 and R19). Furthermore, catchability estimates decreased for age 6 and older ages.

A simpler model configuration, grouping age 2 to 5 (mod 5) resulted in a further improvement in model fit (both based on the AIC and likelihood ratio test).

Allowing the catchability for ages 6 to 8 to be estimated separately from the catchability for younger ages, although supported by inspection of goodness of fit criteria's, had substantial consequences on the abundance and fishing mortalities estimated for these older age classes, and therefore for the SSB of the stock (figures 4 to 6). The catchability estimates for ages 6-8 in mod 5 being lower, higher abundances for these age-classes were estimated for mod 5 than for mod2, which, converted into spawning biomass, resulted in a much higher SSB (50% higher in the last years of the assessment period). The fishing mortality for age 6 to 8 was lower in mod 5 (at similar values as for ages 4-5) than in mod 2. While mod 2 gives the perception of a fisheries targeting particularly the older age groups (F increasing until age 8), the mod 5 suggested that older age were not selected more than ages 4-5.

Model parameters were very similar between mod 2 and mod 5 (figure 7). Apart from the differences in the estimated catchabilities (linked to the different configurations) there were only marginal (not significant) differences in the other parameter estimated, with a slightly lower observation (catches) and process error standard deviations for mod 5. These differences were too small to represent a criteria for deciding that mod 5 is a better configuration (because of resulting in less noise both in observations and in processes) than mod 2.

Inspection of model diagnostics did not bring any clear suggestion either that one configuration was better specified than the other. Model uncertainty on Fbar was in general larger for the mod 2 configuration (figure 8), but the difference was small. Uncertainty on SSB was also slightly larger for mod 2, but not for all years, and in particular not over the recent years. The residual plots for both model configurations were very similar, with marked patterns in both cases (e.g. positive year effect in the catches in 2010, blocks of negative residuals in the catches at the end of the 1990s/early 2000s, year effect in the survey in 2000, etc...). The process error expressed as deviations in abundance showed also a very similar pattern, with slightly larger deviations for mod 2 (related to the slightly higher process error standard deviation).

It is difficult to understand why the catchabilities for ages 6 to 8 are estimated lower that younger age when the model is let free to estimate them. Further investigations would be required to find out what "informs" the model that the fishing mortality is lower and abundance higher on older fish.

Two aspects of mod 5 were however judged doubtful by the participants in the benchmark meeting :

- First, there is no indication from the survey (i.e. from the spatial distribution of different age-groups) supporting the fact that older ages become less available to the survey
- Second, the observation was made that the fishery in the recent years was dominated by long liners, targeting specifically the larger individuals, which is contradictory with the plateau observed for most years in the fishing mortality at age from mod5.

Although the mod 5 configuration is better from a statistical point of view, some of its output are contradictory with expert knowledge on surveys and on the fishery. Investigations looking at parameter correlations, and decomposing the contribution of different observations to the likelihood could provide some additional insight.

Correlation in observation errors

Given the clear patterns in the residuals observed for both the survey and the catches, it seemed appropriate to test a model with correlations between ages in the observation errors. As a first attempt, a unstructured correlation matrix (mod 6) was estimated (i.e. with one parameter estimated for each pair of ages, 28 parameters for each source of information) based on the model configuration mod5.

Model fit criteria indicate that the model improved significantly when correlated errors are incorporated (table 1). The estimated correlations were high between observation errors on the catches for ages 4 to 8, and, to a smaller expend for the survey age 3 to 8 (figure 11). At the same time, the stdev for the catches in mod 6 are estimated much higher than in mod 5 (figure 12). Given the magnitude of the correlations estimated in the catch data, the actual amount of information contained by this data source is actually much lower than previously estimated, and the assessment down-weights (i.e. estimates a higher observation error) for this data source. This has an impact on the stock numbers estimated, as the assessment mod 6 mostly follows the information from the survey, compared to the mod 5 which gave similar weights to both data sources.

Given the large correlations estimated (which are consistent with the patterns described in the residuals for mod 5 on figure 9), it seems appropriate to use a model with correlated observation errors. The configuration tested here, however, is probably not optimal, due to the large number of parameters to be estimated. SAM also offers the possibility to use a correlation matrix with an AR1 structure, which basically assumes that correlation is the same (1 single parameter estimated instead of 28 matrix) between all pairs of consecutive ages, and decreases exponentially as ages are further apart. AR1 structure can also be defined per blocks of age, which is probably a more appropriate solution here, given the strong structuration of the correlation observed. For lack of time, this option could not be investigated during the benchmark.

Investigation of time and age varying natural mortality.

During the benchmark meeting, time-varying/age-dependent natural mortality estimates were presented for cod 3M, produced by the multispecies model GADGET implemented for the Flemish Cape ecosystem. Different versions of the model were presented, resulting in different basal (or residual) natural mortality values (mortality not explain by predation/cannibalism). One of these matrices, with a residual M of 0.2, close to the value (0.19) used in the cod 3M assessment, was used to fit the SAM model. This M matrix differed from a constant M mostly for ages 1 to 4, with higher M values at the start and the end of the time series due to higher cannibalism in the years when the stock was not collapsed. The influence of using this time varying M was explored on the model configuration mod 2.
The magnitude of the observation errors (stdev) was not substantially modified by the inclusion of the time varying M (figure 13). The magnitude of the process error increased slightly. Survey catchability was estimated larger. At the same time, estimated numbers at age were slightly smaller when the M from GADGET was used (not shown), and which resulted in a SSB lower (by 20 000t in the recent years).

One of the improvements expected from the incorporation of a potentially more realistic M matrix was the reduction of the patterns visible in the process error. Indeed, figure 10 shows that the deviations in N, supposed to be independent and identically distributed, actually showed some structure (both correlation between ages, and temporal autocorrelations). Part of this structure could be due to the existence in trends in the real M, not captured in the constant M used, which would result in autocorrelated process deviations. Using the M from GADGET did not make this structure disappear, and, on the opposite, it resulted in a model with a larger process error.

References

FRAMEWORK CONTRACT – EASME/EMFF/2016/008 - for the provision of scientific advice for fisheries beyond EU waters.

Nielsen, A & Berg, CW 2014, 'Estimation of time-varying selectivity in stock assessments using state-space models' Fisheries Research, vol 158, pp. 96-101. DOI: 10.1016/j.fishres.2014.01.014.

Tables

Table 1. List of SAM runs carried out for the 3M cod benchmark. For the different types of parameters (catchability for the EU survey, standard deviation of the process and observation errors), the number indicate for which age-class a specific parameter was estimated (e.g. 1,2,3-8 meaning 3 parameters were estimated, for age 1, for age 2, and a unique parameter for ages 3 to 8). For each run the Akaike information criterion (AIC) is provided for model comparison. When possible, a likelihood ratio test was also performed to test whether the addition of a particular parameter significantly improved model fit.

	catchabilities		**Process stdev**		**Observation stdev**		**Nr. params**	**AIC**	**Log-likelihood ratio test**
Run name	**EU survey**	**exponent**	**Var F random walks**	**Var logN**	**Catches**	**EU survey**			
SAM R19	1,2,3-8	1	1,2-8	1,2-8	All ages	All ages	24	1130.69	
SAM R15	1,2,3-8	1	1,2-8	1,2-8	1-2,3-6,7-8	1,2-8	13	1130.17	
Compare different configurations for observation stdev									
SAM mod2	1,2,3-8	1	1,2-8	1,2-8	1-2,3-6,7-8	1-8	12	1128.30	P = 0.71 (modR15 vs mod2)
SAM mod2.2	1,2,3-8	1	1,2-8	1,2-8	1-2,3-6,7-8	1-2,3-8	13	1127.72	P = 0.10 (Mod2.2 vs 2)
SAM mod3	1,2,3-8	1	1,2-8	1,2-8	1-8	1-8	10	1130.08	P = 0.035 (mod2 vs mod3)
Compare different configurations for catchabilities									
SAM mod4	All ages	1	1,2-8	1,2-8	1-2,3-6,7-8	1-8	17	1114.71	P= 0.0002 (mod 2 vs mod4)
SAM mod5	1,2-5,6,7,8	1	1,2-8	1,2-8	1-2,3-6,7-8	1-8	14	1109.27	P= 0.90 (mod 4 vs mod5)
Compare runs with observation error structure									
SAM mod6	As model 5 but with unstructured correlation matrices for observation errors catches and survey						70	1053.33	P=0 (mod6 vs mod5)

Figures

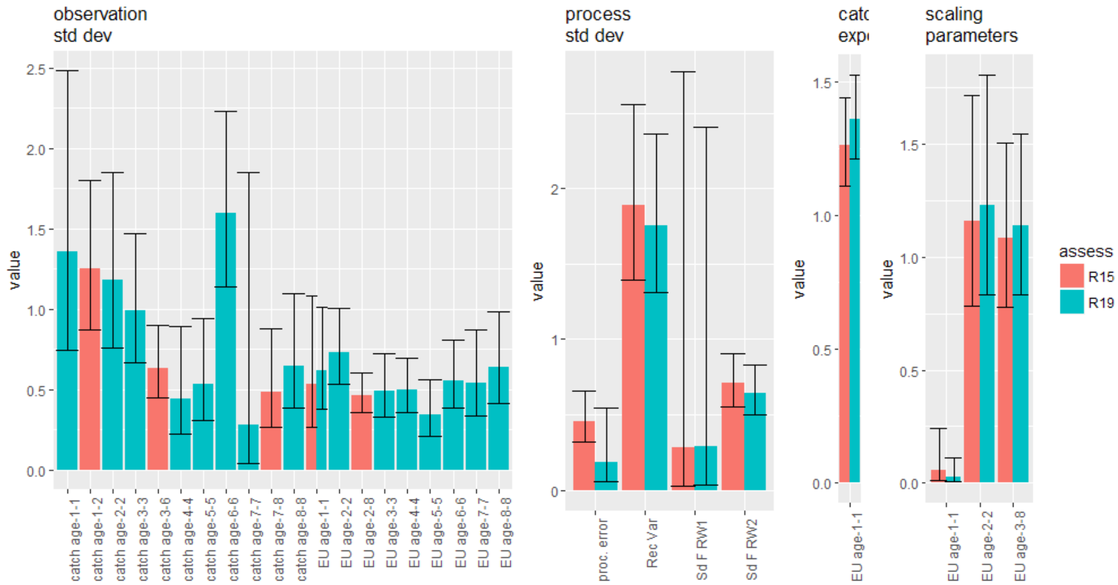

Fig. 1. Parameter estimates (and confidence bounds) for the SAM runs with configuration R15 and R19. The first block shows the standard deviations for the observation errors (catches and EU survey), for specific age (or age groups), the second block show the standard deviations of processes (process error on N, recruitment random walk, fishing mortality random walks), the third block is the exponent on abundance applied to model the survey index, the last block presents the catchability estimates for the EU survey per age (groups).

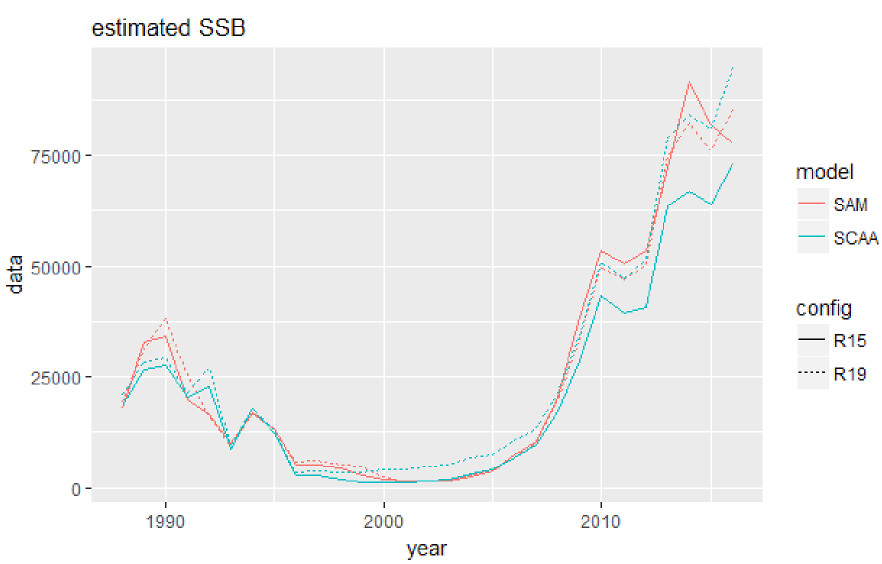

Fig. 2. Estimated SSB from SAM and from the SCAA for the configurations R15 and R19..

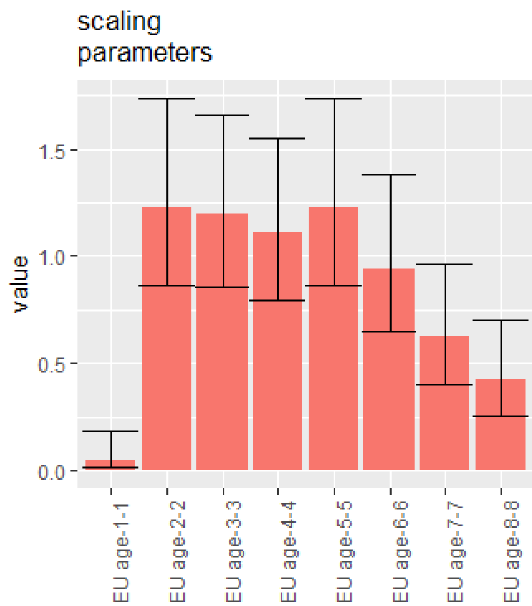

Fig. 3. Age specific estimates for the survey catchability in mod4.

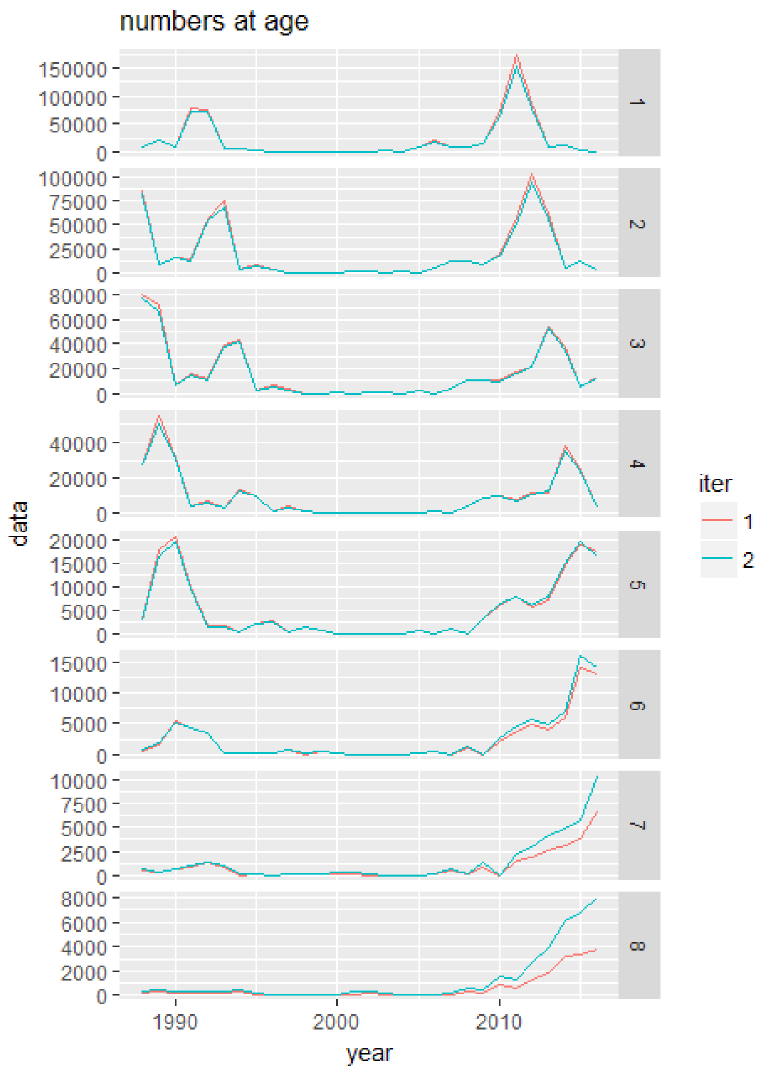

Fig. 4. Comparison of the abundance at age estimates from SAM runs mod 2 (red) and mod 5 (blue).

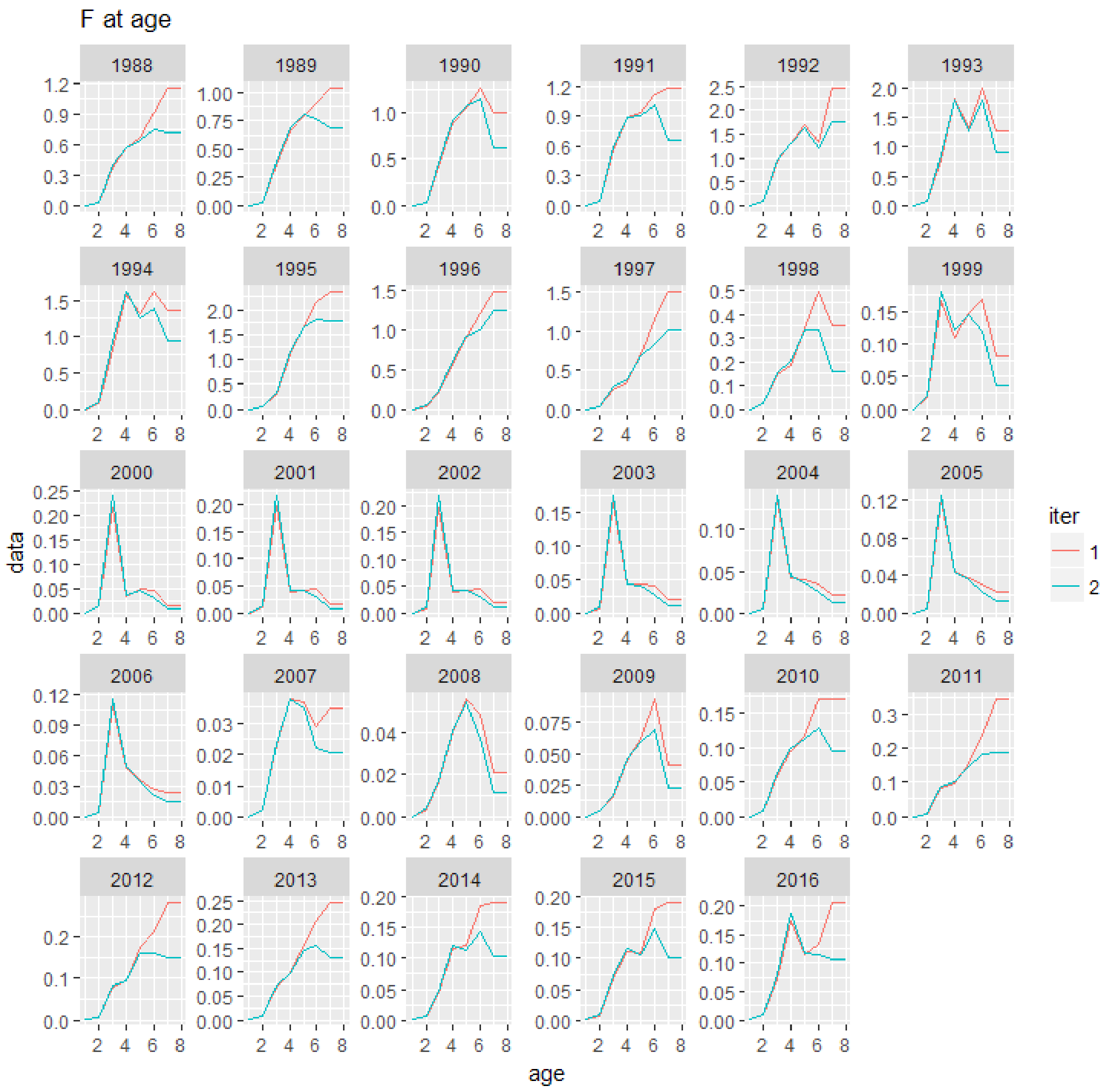

Fig. 5. Estimates for fishing mortality at age from SAM run mod2 (red) and mod5 (blue).

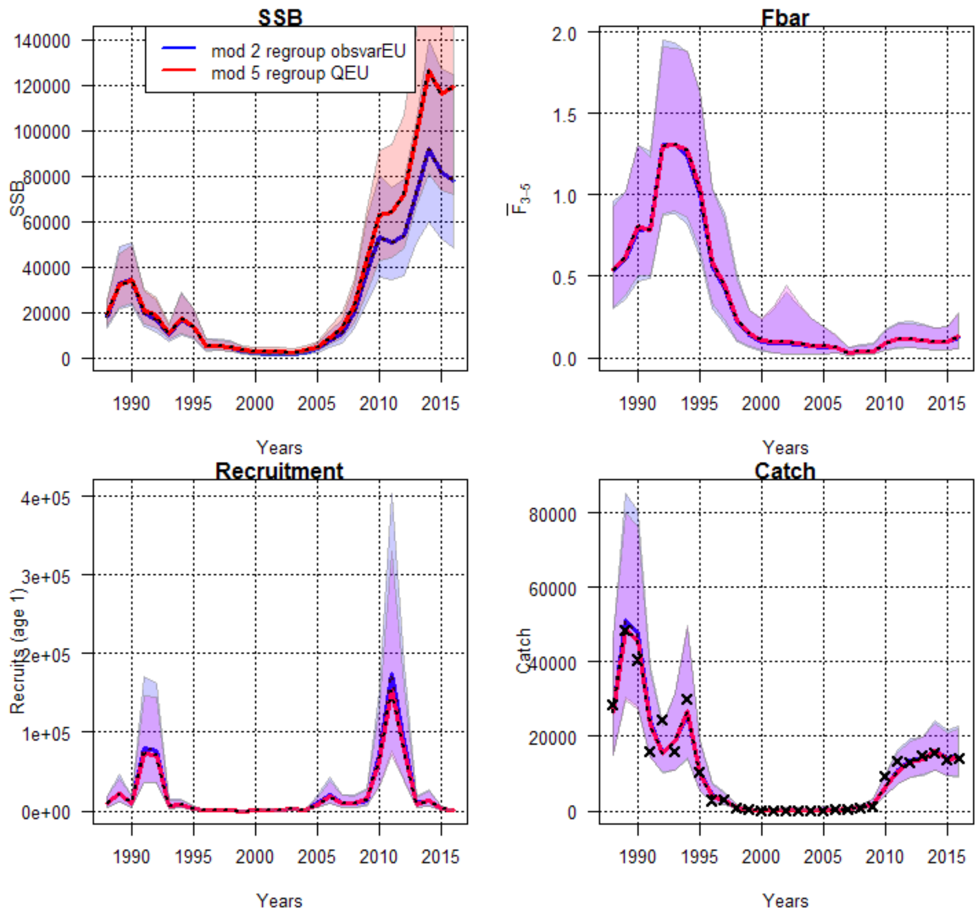

Fig. 6. Comparison of SSB, Fbar, recruitment and modelled catches from SAM run mod 2 and mod5.

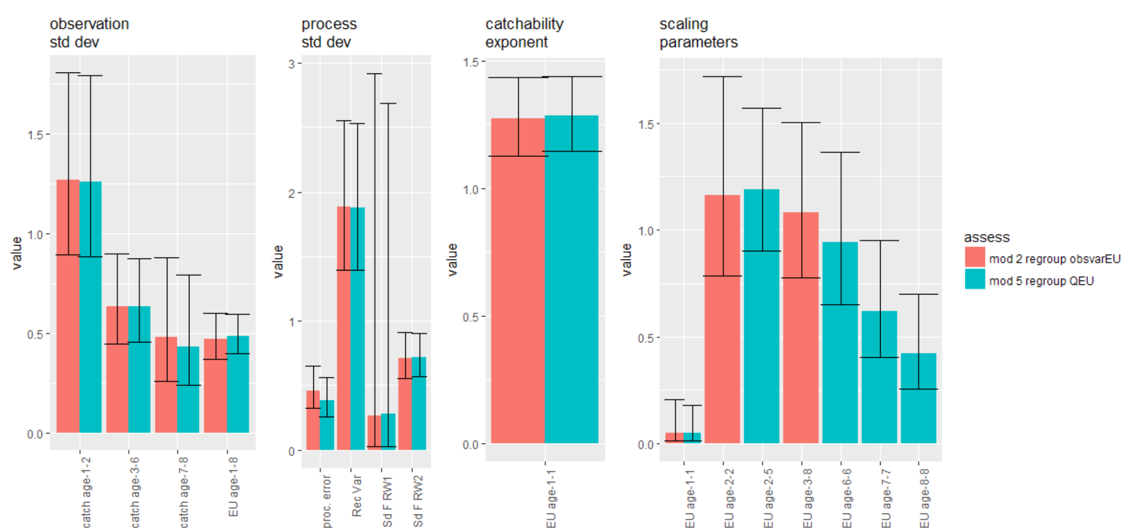

Fig. 7. Comparison of model parameters between configuration mod2 and mod5

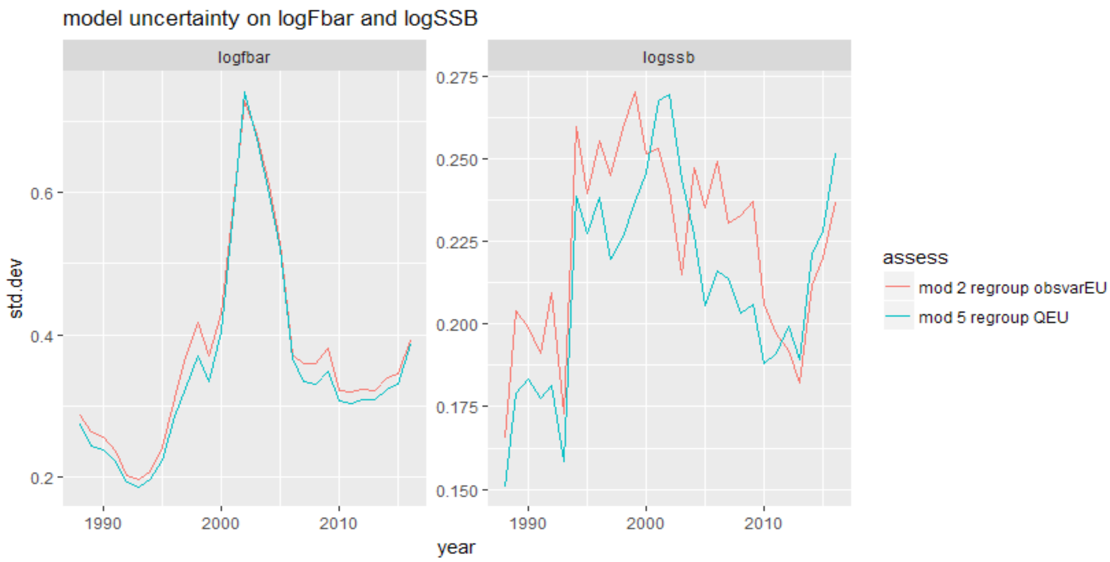

Fig. 8. Model uncertainty (estimates of standard deviations on the log SSB and log Fbar) for model configuration mod 2 and mod 5.

Fig. 9. One-step-ahead residuals for the catches (top) and the EU survey (bottom) for the SAM run with mod 2 and mod 5 configurations.

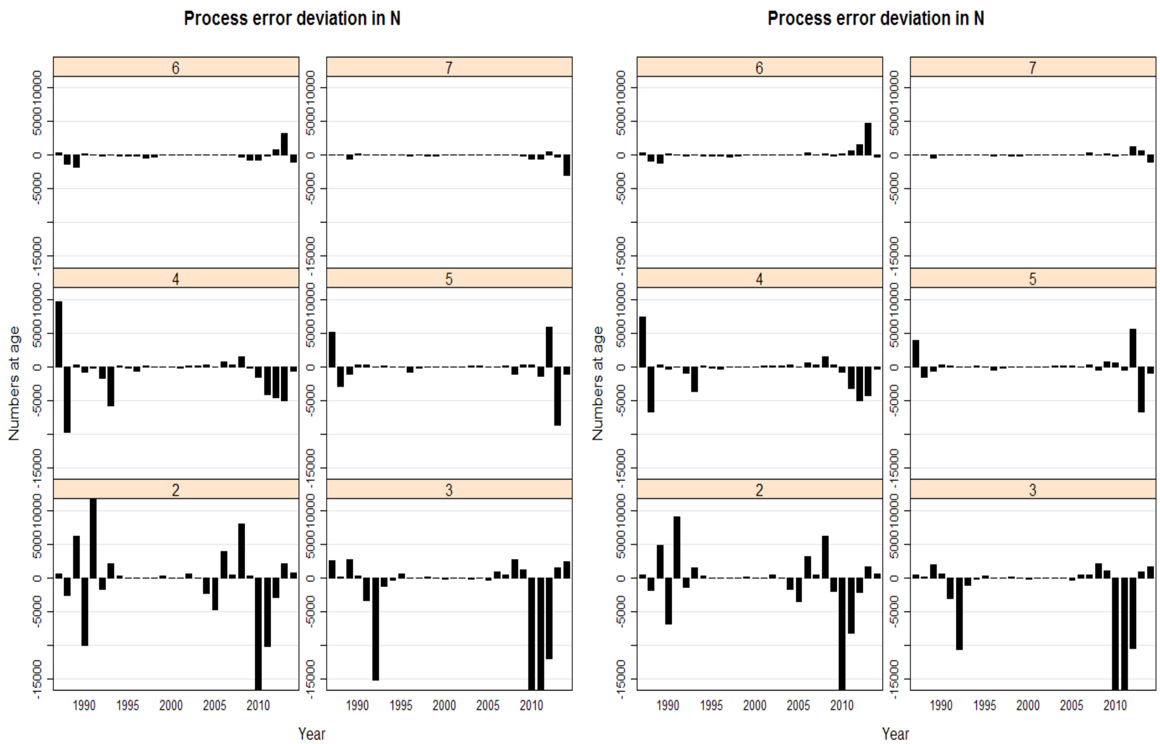

Fig. 10. process error realisation for ages 2 to 7 for model configuration mod 2 and mod5. Process error here are the differences between the model estimate of Na,y, and the value computed using the survival equation from the estimates Na-1,y-1 and Za-1,y-1.

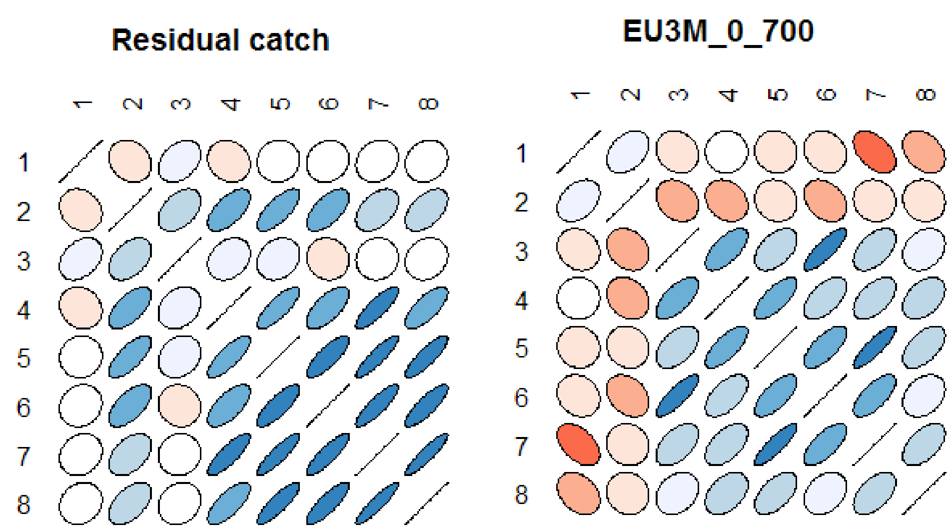

Fig. 11. Estimated correlation structures for the observation errors for the catches and the survey (from model mod6).

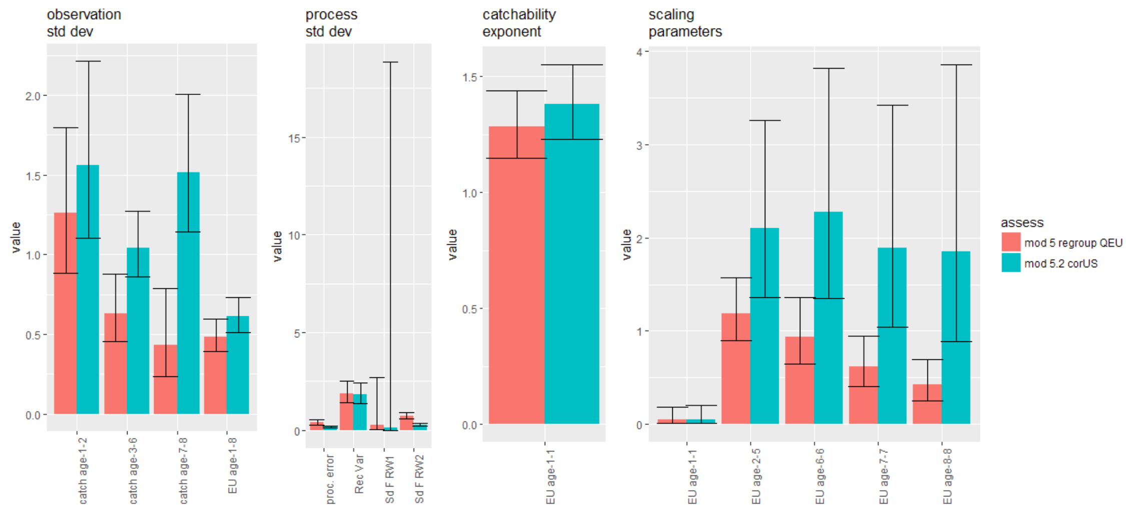

Fig.12. Parameters estimates for mod 5 and mod 6.

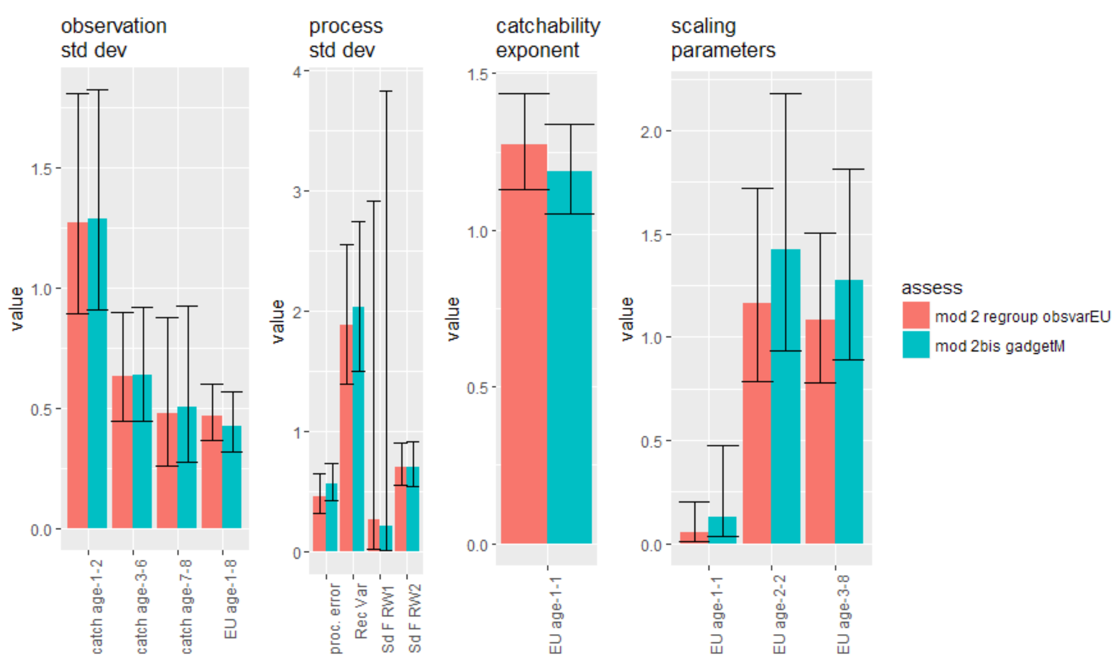

Fig.13. Parameters estimated for model configuration 2 with a constant M equal to 0.19 for all ages, and with a time/age varying M estimated by GADGET.