Annex 7: Faroe saithe – adjustments of the SAM model configuration

This annex was added to the report in November 2020, and contains two working documents as well as review of these.

- Adjustments of the SAM model configuration for Faroe saithe (5b)-UPDATE 2019
  Luis Ridao Cruz, luisr@hav.fo, Faroe marine resarch institute, FAMRI

- Re-evaluation of biological reference points for Faroe saithe (pok.27.5b)
  Luis Ridao Cruz, luisr@hav.fo, Faroe marine resarch institute, FAMRI

- Review of: Adjustments of the SAM model configuration for Faroe cod and saithe (5b)

Please note: the changes and review refer to cod and saithe while in the end, the model was only changed for saithe

Adjustments of the SAM model configuration for Faroe saithe (5b)-UPDATE 2019

Luis Ridao Cruz, luisr@hav.fo

Faroe marine resarch institute, FAMRI

The SAM model was adopted as the basis of advice for Faroe saithe (5b) in 2017 (WKFAROE, **stock annex**) The present document illustrates the implementation of some adjustments in the SAM model configuration. The motivation for this analysis was to improve the overall fit of the model and reduce the bias associated with the assessment. The configuration options for the SPALY assessment are as follows (some configuration options omitted):

```
##                      minAge                      maxAge
##                           3                          15
##                  fbarRange1                  fbarRange2
##                           4                           8
## stockRecruitmentModelCode                      corFlag
##                           0                           2
```

```
## $keyLogFsta
##      [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11] [,12] [,13]
## [1,]    0    1    2    3    4    5    6    7    8     8     8     8     8
## [2,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1    -1    -1
## [3,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1    -1    -1
##
## $keyLogFpar
##      [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11] [,12] [,13]
## [1,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1    -1    -1
## [2,]    0    1    2    3    4    5    6    6   -1    -1    -1    -1    -1
## [3,]    7    8    9   10   11   12   13   13   -1    -1    -1    -1    -1
##
## $keyVarF
##      [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11] [,12] [,13]
## [1,]    0    0    0    0    0    0    0    0    0     0     0     0     0
## [2,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1    -1    -1
## [3,]   -1   -1   -1   -1   -1   -1   -1   -1   -1    -1    -1    -1    -1
##
## $keyVarObs
##      [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11] [,12] [,13]
## [1,]    0    0    0    0    0    0    0    0    0     0     0     0     0
## [2,]    1    2    3    3    3    3    3    3   -1    -1    -1    -1    -1
## [3,]    4    5    6    6    6    6    6    6   -1    -1    -1    -1    -1
##
## $obsCorStruct
## [1] ID AR ID
## Levels: ID AR US
##
## $keyCorObs
##      3-4 4-5 5-6 6-7 7-8 8-9 9-10 10-11 11-12 12-13 13-14 14-15
## [1,]  NA  NA  NA  NA  NA  NA   NA    NA    NA    NA    NA    NA
## [2,]   0   0   0   0   0   0    0    -1    -1    -1    -1    -1
## [3,]  NA  NA  NA  NA  NA  NA   NA    -1    -1    -1    -1    -1
```

The options for observation correlation coupling is an AR(1) (observation correlation structure) for the summer survey, i.e., observations are correlated for all age classes (3 -10) whereas for the spring survey there is no correlation coupling between ages (ID). The coupling of observation variances specifies the options for observation noise for both catches and survey indices. For the SPALY run there is one variance component for the catch observations while for both the summer and the spring survey variances are different for ages 3 and 4 and coupled for older age groups.

The changes incorporated to the configuration of the model are as follows.

1. Variance componentse for both surveys will be different for all age groups (3-10)
2. Observation correlation coupling for both surveys is set to an AR(1) process.

The implementation of these changes in the assessment for saithe resulted in better model diagnostics. A visual inspection of the residuals plot in the spring index show the absence of blocks of positive and negative residuals in 1998 and 2007 respectively which were observed in the SPALY model (Figure 1). A measurement of the model improvement can be quantified in terms of AIC (Akaike Information Criterion). The AIC for the adopted assessment is AIC(SPALY)=2115 whereas for the new model configuration is estimated at AIC(MOD0)=2012. Other model configurations were also investigated (Table 1). Model parameter and uncertainty associated to the estimates are illustrated in table 2 (MOD0).

The consistency of the new model configuration evaluated in terms of Mohn's rho, which measures the severity of retrospective patterns is also improved (Table 1, Figures 3 and 4). Retrospestive analysis were run in a five year window. An additional four year retrospective run ("MOD0_rho4" column in table) is also presented as an illustrative example of the sensitivity of Mohn's rho to the time period selected. Bias in SSB and recruitment estimates go down from 33% and 50% (SPALY) to 24% and 40% (MOD0) , respectively.

The leave-one-out analysis (Figures 5 and 6) reflects also the model refinement. The elimination of either survey index in the new model configuration results in both smaller discrepancies than those in the SPALY run and more consistent assessment output, i.e., within the model confidence intervals.
Estimated variability of state variables is illustrated in figure 7. The standard deviation of SSB of all the exploratory models are higher than that of the SPALY run but below 0.20 from 2009 to 2018. Variance of Fbar for all the alternative models is lower than the SPALY assessment from 20109 to 2016 but higher thereafter. For both the MOD0 and SPALY models variablity in Fbar is estimated at 0.21 and 0.18 respectively.

Stock parameters such as spawning stock bimass (SSB), average fishing mortality (F_{bar}), recruitment numbers (age 3) and observed and predicted landings are shown in figure 8 for both the SPALY and the best model run (MOD0). Both agree in the historical perception of the stock but they disagree in the most recent stock dynamics. Thus it's expected that estimates of biological reference points will be very close to current values. Whereas the SPALY assessment suggests that fishing mortality in 2019 is below F_{msy}=0.30 the MOD0 model estimates F at a higher rate and therefore a lower predicted SSB. The recruitment estimates of MOD0 in recent years are below historical average and also lower than the adopted assessment. Model fit to catch and survey at age matrices are illustrated in figures 9-11.

Table 1: Faroe saithe 5b. Mohn's rho for SPALY and alternative model configurations. Calculations based on a 5-year window. Rightmost row shows Mohn's rho on a 4-year period (MOD0_4).

	R(age 3)	SSB	Fbar(4-8)	AIC
SPALY	49.8	32.6	5.9	2114.9
MOD0	39.7	23.8	4.7	2012.4
MOD1	43.2	25.4	2.3	2023.7
MOD2	41.6	23.9	3.1	2036.1
MOD3	46.0	28.9	1.8	2042.4
MOD0_4	34.5	18.4	7.7	2012.4

Table 2: Faroe saithe 5b. Table of selected model parameters (MOD0).

	par	sd(par)	exp(par)	Low	High
logFpar_0	-7.6248898	0.2494171	0.0004881	0.0002964	0.0008039
logFpar_1	-7.0366432	0.1941423	0.0008791	0.0005962	0.0012961
logFpar_2	-6.6775261	0.1822353	0.0012589	0.0008744	0.0018125
logFpar_3	-6.7732568	0.1202054	0.0011440	0.0008995	0.0014549
logFpar_4	-6.9554693	0.1269634	0.0009534	0.0007396	0.0012290
logFpar_5	-6.9987106	0.1166320	0.0009131	0.0007231	0.0011529
logFpar_6	-7.0437632	0.1466969	0.0008728	0.0006509	0.0011704
logFpar_7	-8.4328091	0.2599247	0.0002176	0.0001294	0.0003660
logFpar_8	-7.5506476	0.2046683	0.0005258	0.0003492	0.0007917
logFpar_9	-7.2502588	0.1315865	0.0007100	0.0005457	0.0009237
logFpar_10	-7.1230552	0.0936471	0.0008063	0.0006686	0.0009724
logFpar_11	-7.2988672	0.0915332	0.0006763	0.0005632	0.0008122
logFpar_12	-7.1816729	0.0980355	0.0007604	0.0006250	0.0009251
logFpar_13	-7.0992775	0.1132833	0.0008257	0.0006583	0.0010357
logSdLogFsta_0	-1.4364131	0.1203329	0.2377791	0.1869192	0.3024778
logSdLogN_0	-0.7221061	0.1598354	0.4857282	0.3528272	0.6686896
logSdLogN_1	-1.4015690	0.1108479	0.2462104	0.1972537	0.3073177
logSdLogObs_0	-0.9122594	0.0458611	0.4016158	0.3664176	0.4401951
logSdLogObs_1	0.0750871	0.1517860	1.0779780	0.7957383	1.4603251
logSdLogObs_2	-0.2075604	0.1535134	0.8125642	0.5977473	1.1045813
logSdLogObs_3	-0.2795387	0.1496965	0.7561325	0.5604969	1.0200526
logSdLogObs_4	-0.8439984	0.1615852	0.4299878	0.3112469	0.5940285
logSdLogObs_5	-0.7888165	0.1494388	0.4543822	0.3369926	0.6126638
logSdLogObs_6	-0.9723459	0.1588240	0.3781948	0.2752724	0.5195991
logSdLogObs_7	-0.7022671	0.1558807	0.4954608	0.3627547	0.6767146
logSdLogObs_8	-0.4301396	0.1726447	0.6504183	0.4605062	0.9186499
logSdLogObs_9	0.2149693	0.1437475	1.2398238	0.9300419	1.6527891
logSdLogObs_10	-0.0280598	0.1317771	0.9723302	0.7470568	1.2655342
logSdLogObs_11	-0.5361630	0.1329405	0.5849885	0.4484114	0.7631643
logSdLogObs_12	-1.0068785	0.1407952	0.3653577	0.2756926	0.4841851
logSdLogObs_13	-1.0402628	0.1391296	0.3533618	0.2675304	0.4667303
logSdLogObs_14	-0.9293834	0.1390838	0.3947971	0.2989284	0.5214115
logSdLogObs_15	-0.7298151	0.1680266	0.4819981	0.3444286	0.6745147
logSdLogObs_16	-0.0407215	0.1502164	0.9600965	0.7109491	1.2965558
transfIRARdist_0	-1.4956700	0.2743244	0.2240984	0.1294683	0.3878948
transfIRARdist_1	-0.5236584	0.2051895	0.5923496	0.3929640	0.8929012
itrans_rho_0	1.4421156	0.1572342	4.2296346	3.0883814	5.7926164

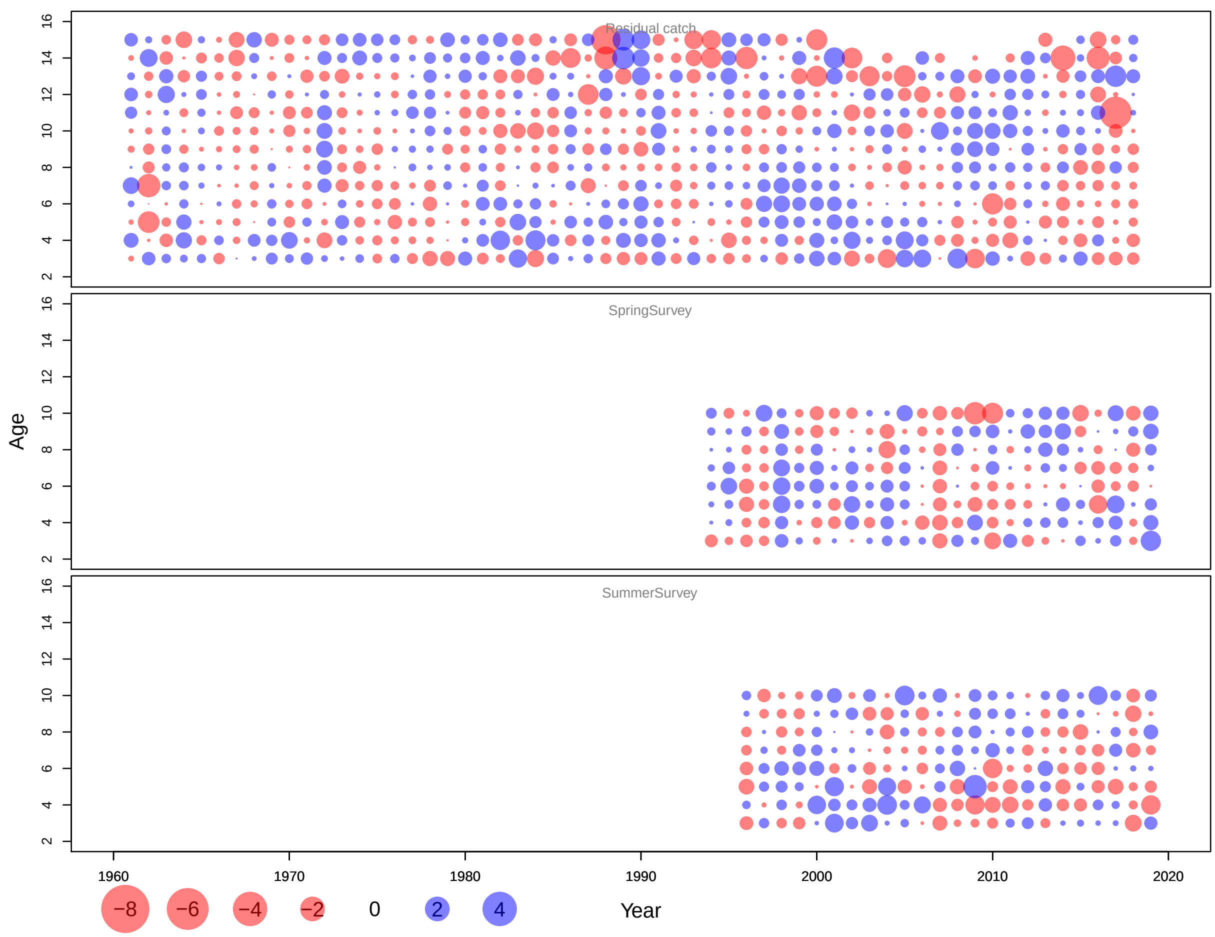

Figure 1: Faroe saithe 5b. Residual plots of the SAM SPALY run

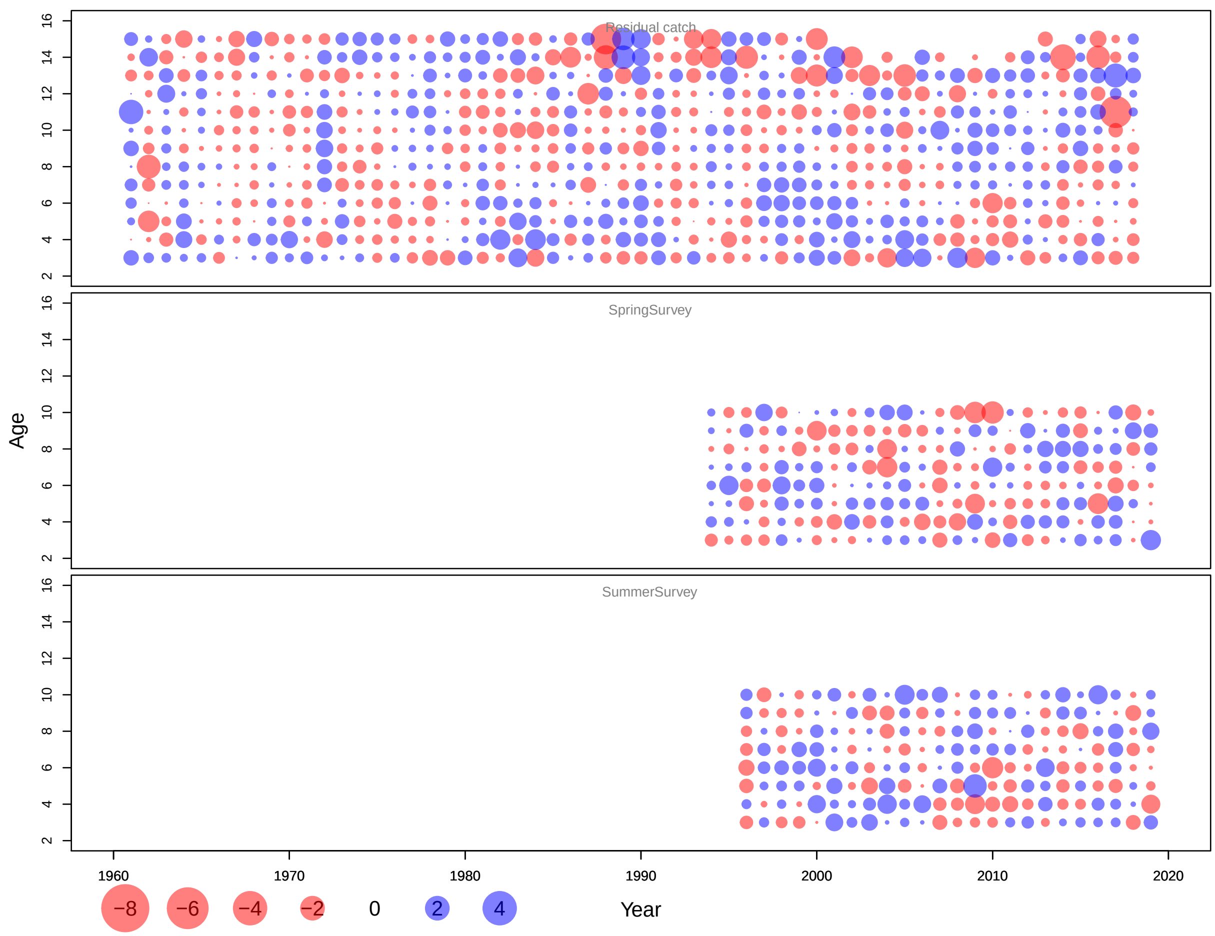

Figure 2: Faroe saithe 5b. Residual plots of the new SAM model configuration (MOD0)

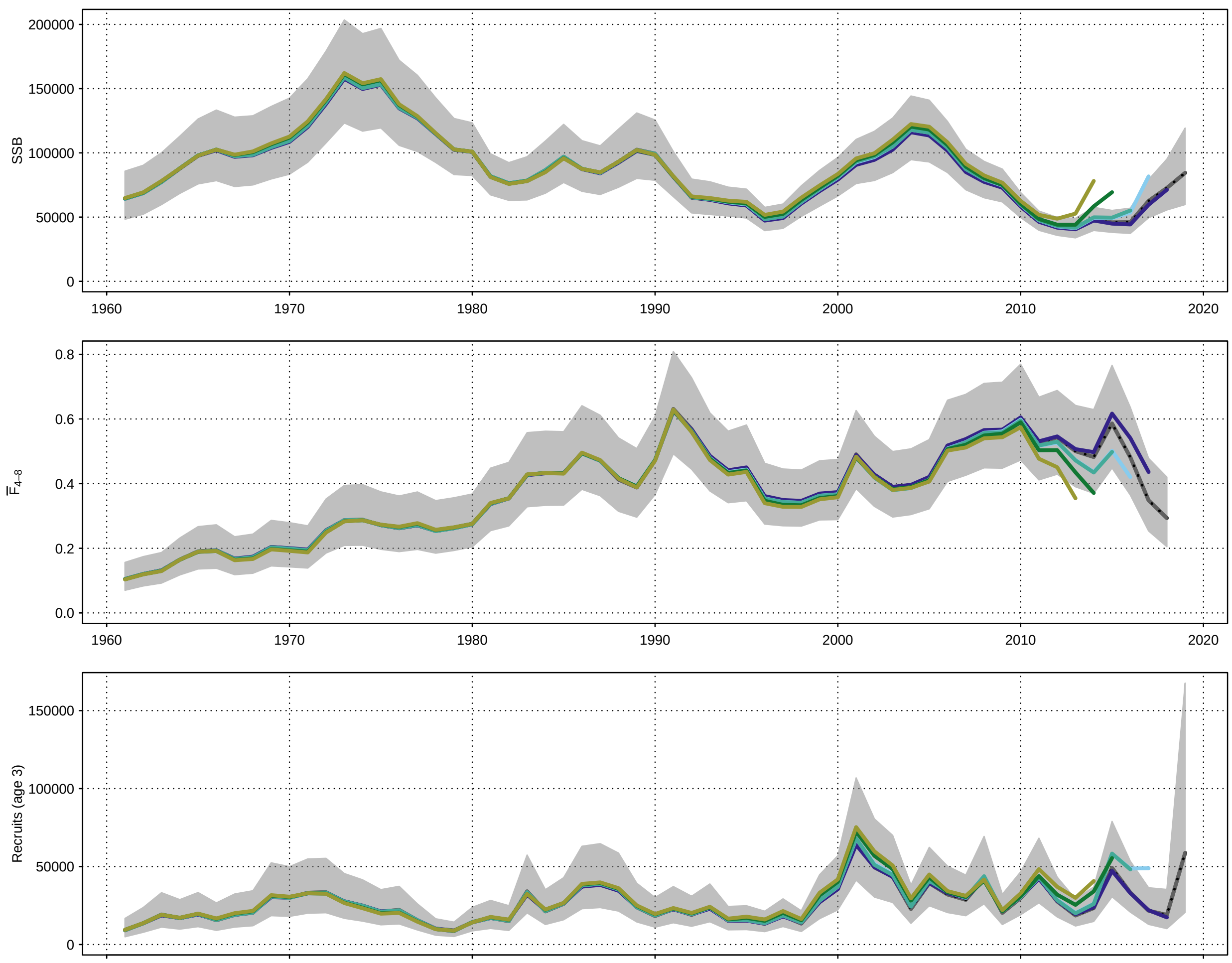

Figure 3: Faroe saithe 5b. Restrospective plots of the SPALY model.

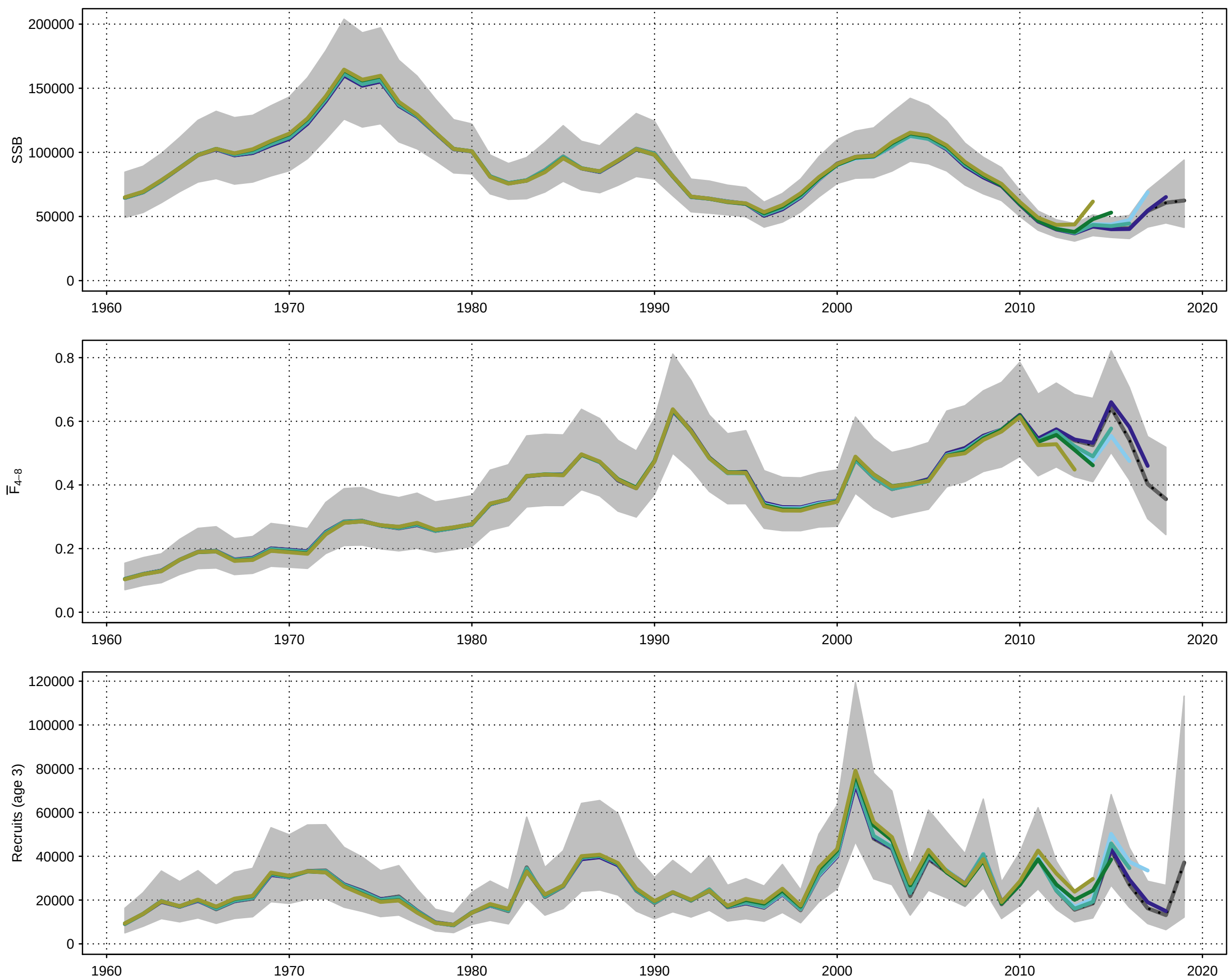

Figure 4: Faroe saithe 5b. Restrospective plots of the new SAM model configuration (MOD0).

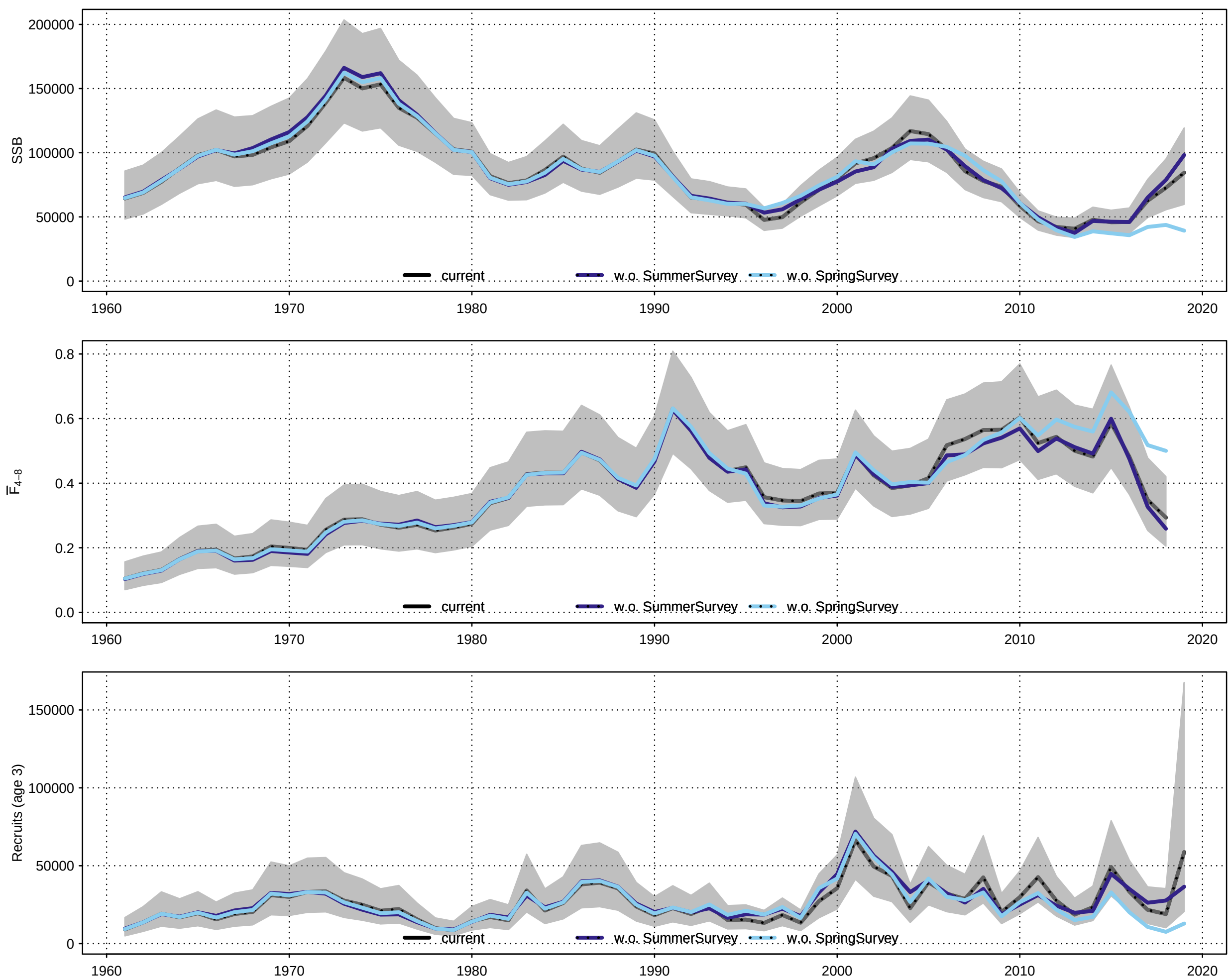

Figure 5: Faroe saithe 5b. Leave-one-ot analysis of the SPALY model.

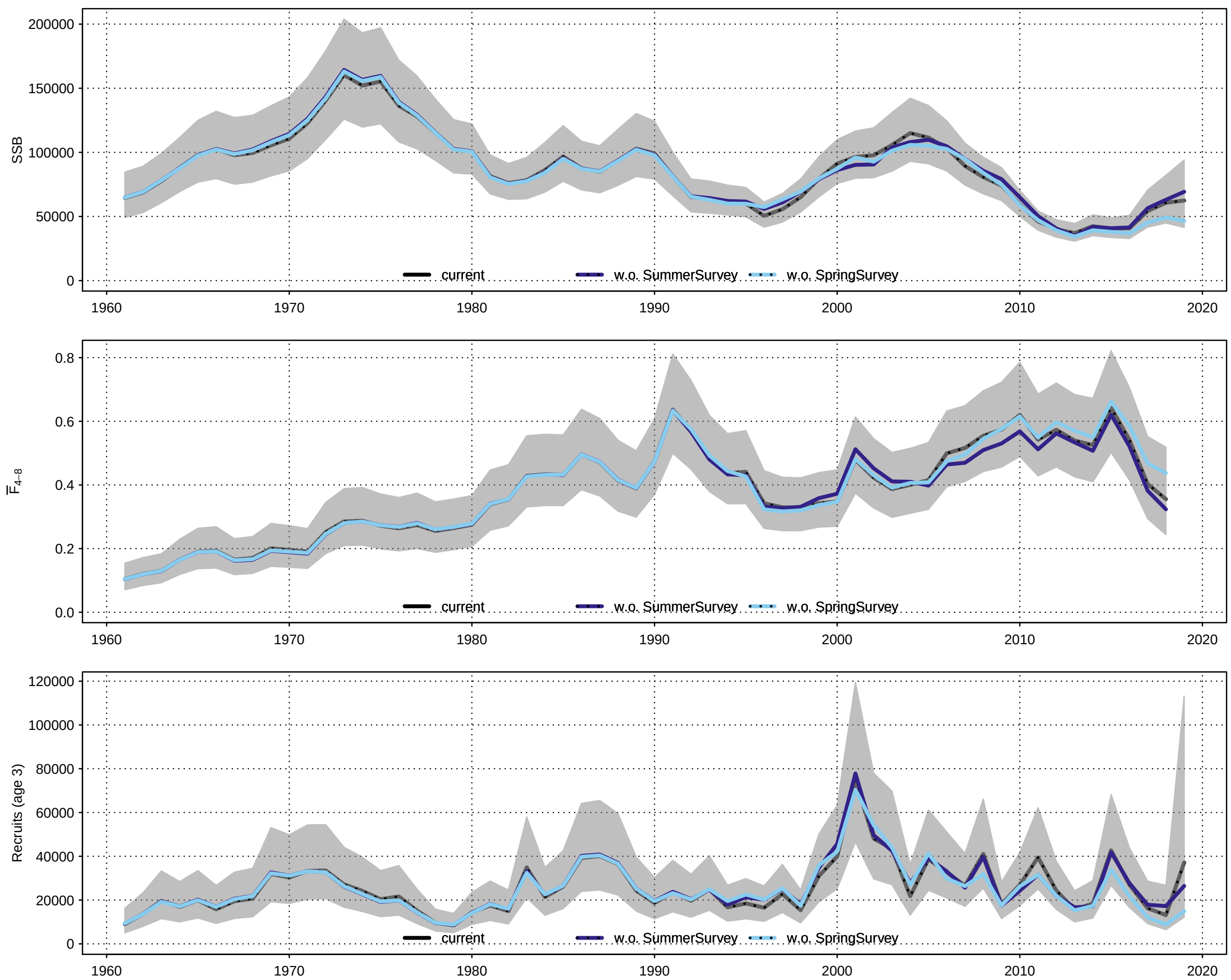

Figure 6: Faroe saithe 5b. Leave-one-ot analysis of the new SAM model configuration (MOD0).

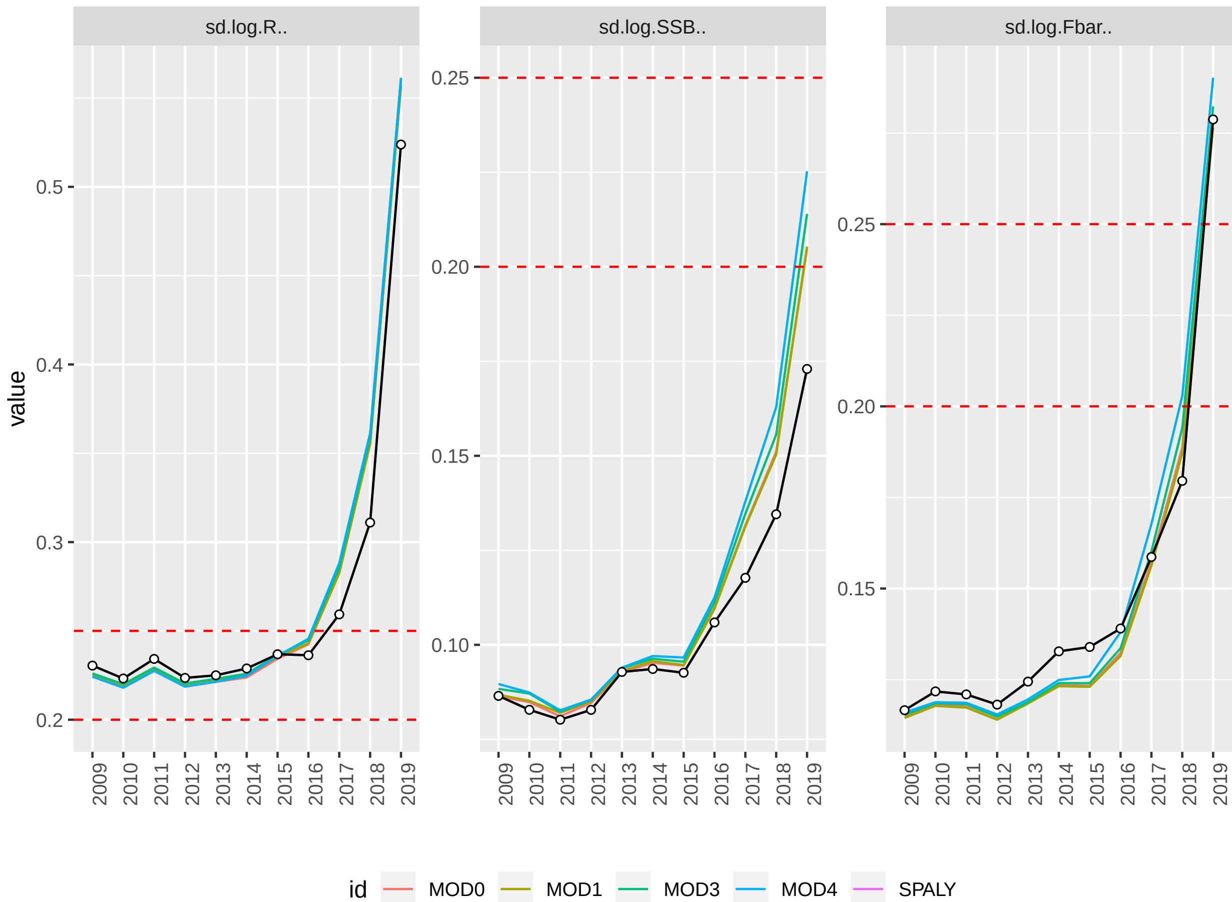

Figure 7: Faroe saithe 5b. Variability in SAM state variables (log-scale) among the models. Recruitment (left), SSB (middle) and Fbar (right). Black circled line represents the SPALY assessment.

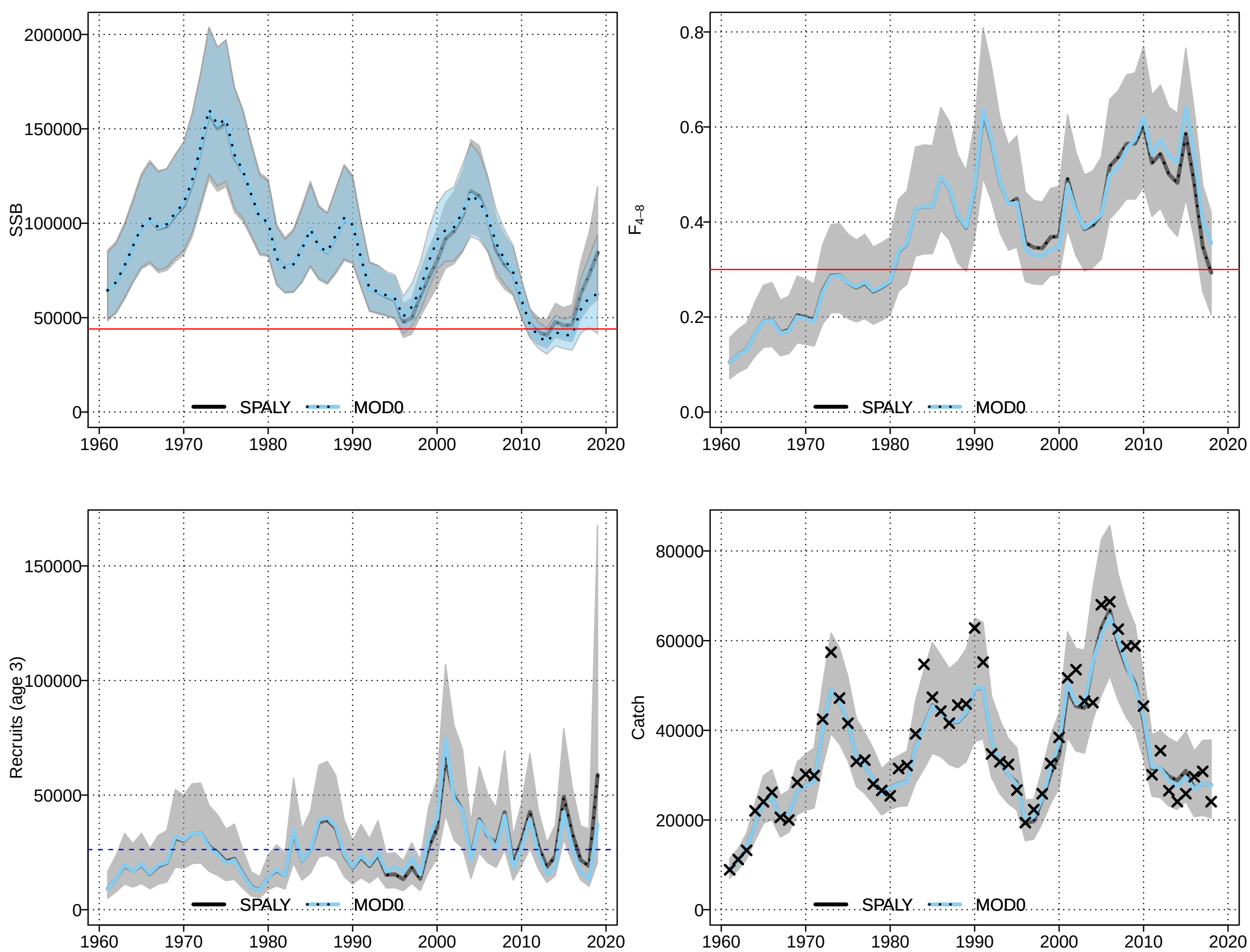

Figure 8: Faroe saithe 5b. SAM model comparison

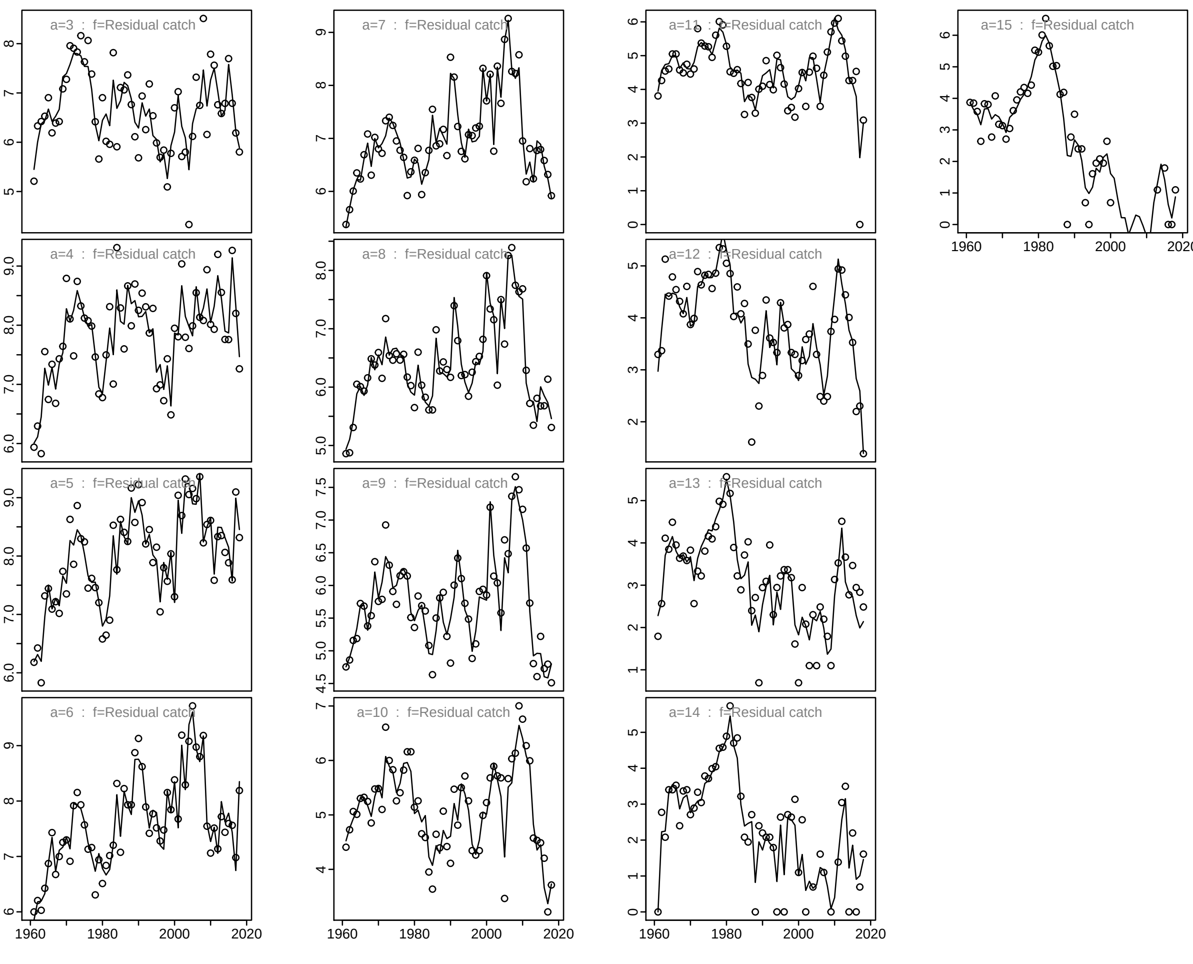

Figure 9: Faroe saithe 5b. SAM model. Fit to catch-at-age matrix.

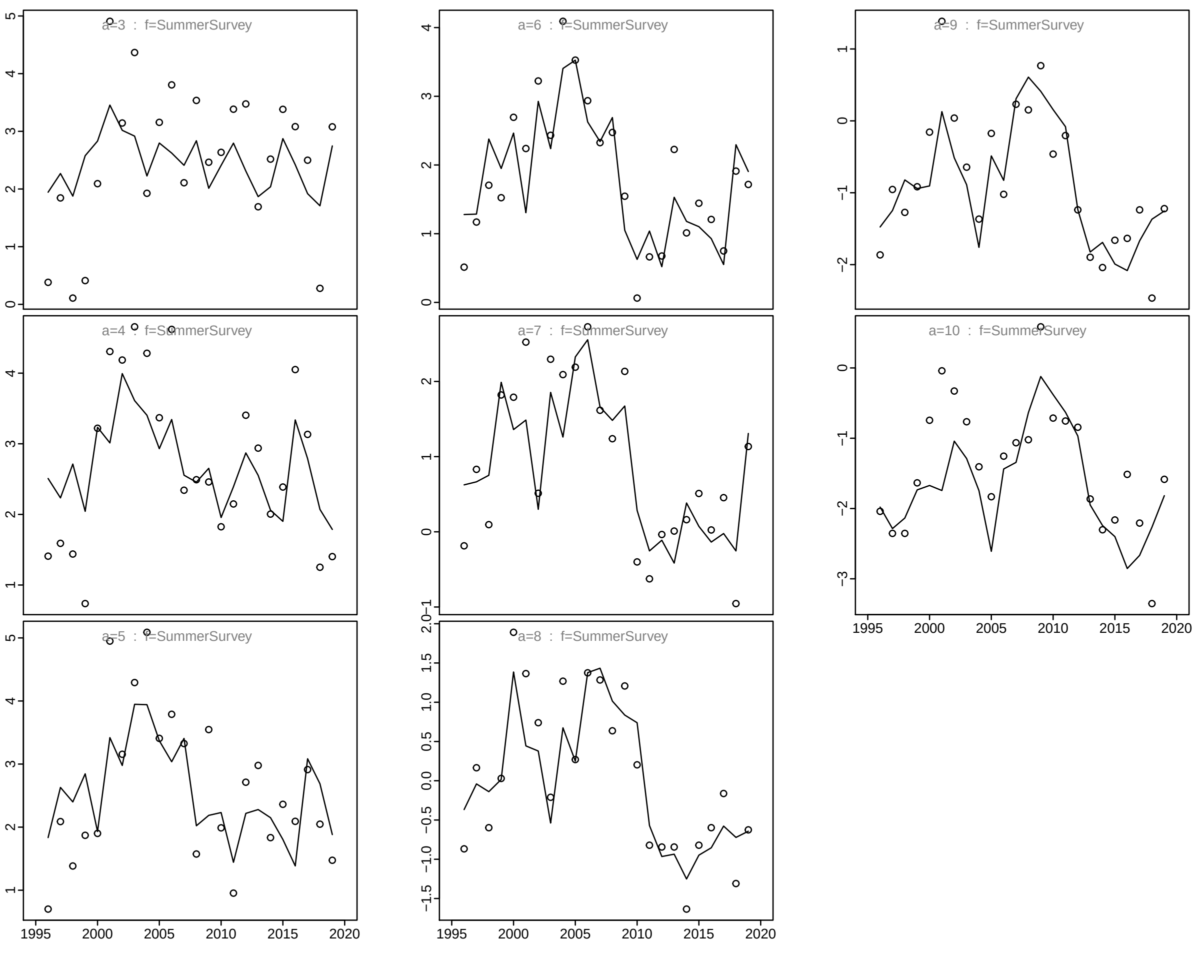

Figure 10: Faroe saithe 5b. SAM model. Fit to summer index catch-at-age matrix.

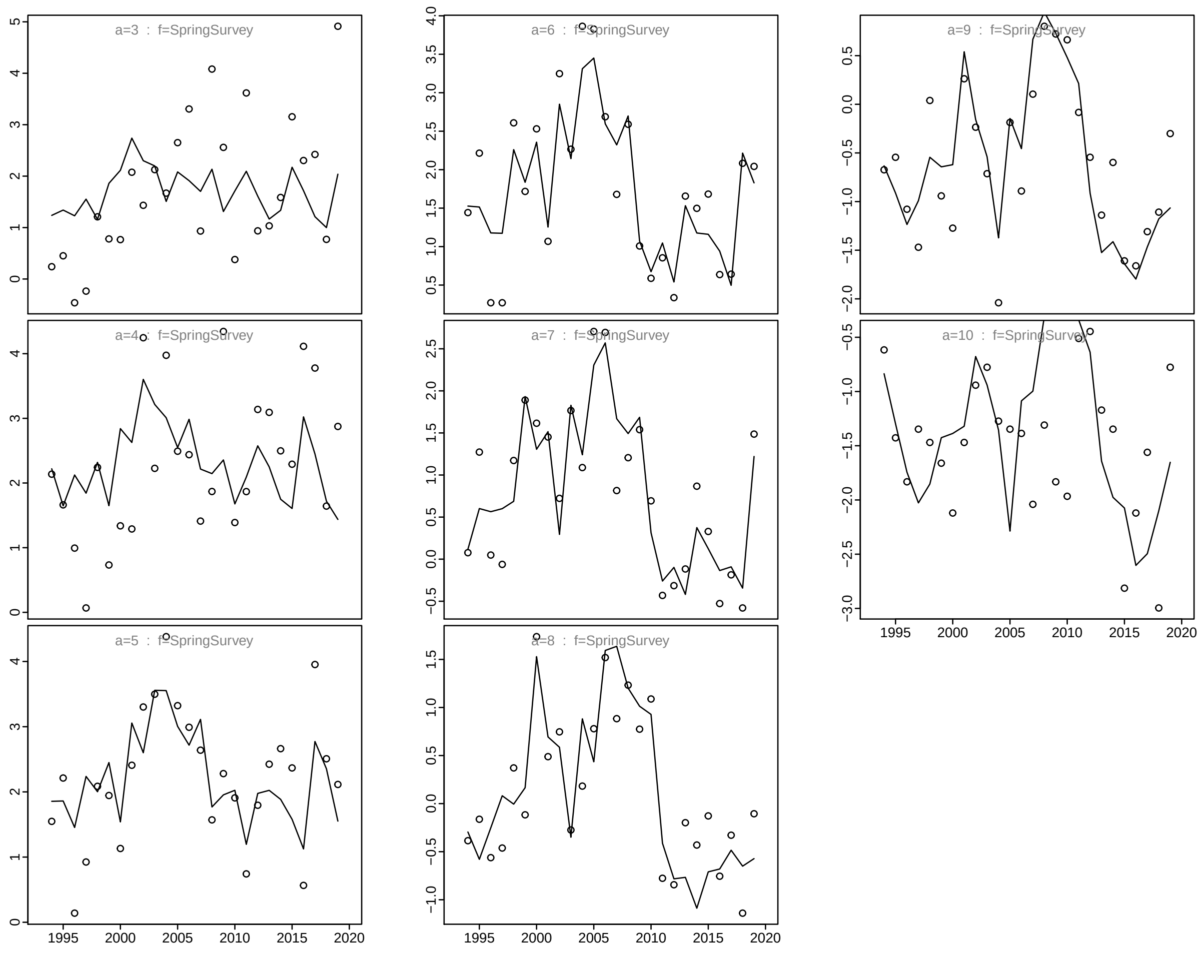

Figure 11: Faroe saithe 5b. SAM model. Fit to spring index catch-at-age matrix.

Re-evaluation of biological reference points for Faroe saithe (pok.27.5b)

Luis Ridao Cruz

Faroe marine resarch institute, FAMRI

Biological reference points (BRPs) for faroe saithe were evaluated at the North-Western Working group meeting (NWWG) and adopted by ACOM in 2017. This document presents a re-evaluation of the BRPs as a consequence of the changes carried out in the configuration of the adopted SAM assessment model in 2019 (Adjustments of the SAM model configuration for Faroe saithe (5b)-UPDATE 2019). The methodology for the re-calculation of reference points has not been modified and therefore it follows the approach described both in the stock annex and in the NWWG report (see annex at bottom of document)

The recommnendation is to keep the current reference points given the negligible differences observed between the 2017 and 2019 reference points.

Figure 1 and table 1 display the results of the re-evaluation of biological reference points.

Table 1: Biological reference points for faroe saithe.

Ref. Points	2017	2019	Notes
B_{pa}	41 400 t	40 700 t	Based on Bloss
$B_{trigger}$	41 400 t	40 700 t	B_{pa}
B_{lim}	29 571 t	29 071 t	$B_{pa}/1.4$
F_{pa}	0.52	0.52	F_{lim} * exp(-0.18 * 1.645)
F_{msy}	0.30	0.29	Simulations, F that gives $P[SSB<B_{lim}]<0.05$
F_{lim}	0.70	0.70	Simulations, F that gives $P[SSB>B_{lim}]=0.5$

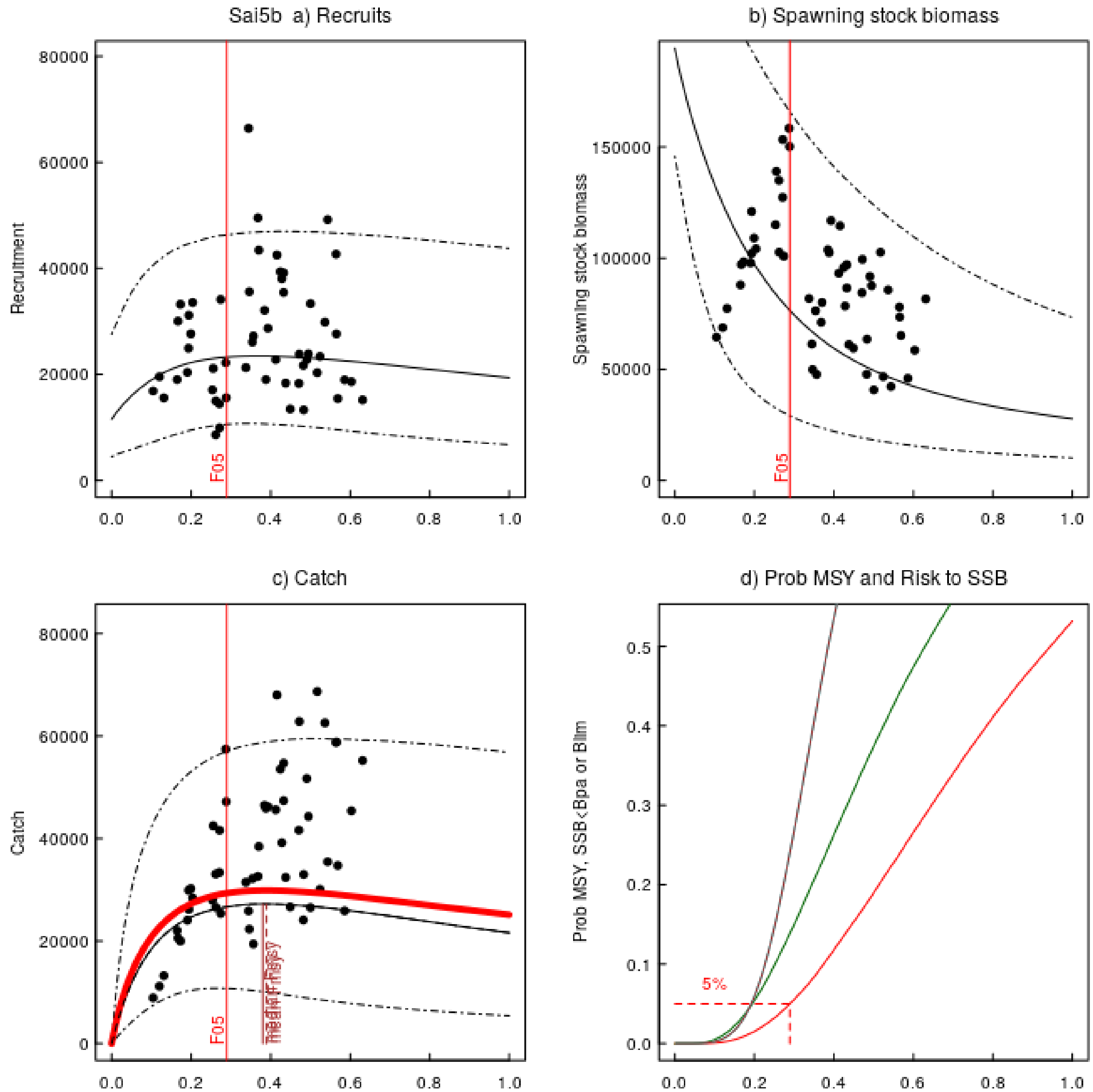

Figure 1: Recruitment, ssb, catch and probability profile from simulations.

Annex

At the NWWG in 2017, reference points were revised according to the ICES guidelines (ICES fisheries management reference points for category 1 and 2 stocks, January 2017) The latest assessment output from 2019 was used as the basis for the simulations. The software to implement the calculations was EqSim. The procedure was as follows:

$B_{pa} = B_{trigger}$ was set to 40 700 t (lowest historical SSB estimated in 2013).

B_{lim} was calculated according the equation: $B_{pa} = B_{lim} \times \exp(\text{sigma} \times 1.645) = 29\ 071$ t. where sigma= 0.20 (as suggested by ACOM)

The F_{msy} estimation process consisted of 3 simulations:

1. Simulation 1. Get F_{lim}

F_{lim} is derived from B_{lim} by simulating the stock with segmented regression S-R function with the point of inflection at B_{lim} .

F_{lim} is the F that, in equilibrium, gives a 50% probability of SSB > B_{lim}

The simulation was conducted with:

- fixed F (i.e. without inclusion of a $B_{trigger}$)
- without inclusion of assessment/advice errors.

2. Simulation 2. Get initial F_{msy}

F_{msy} should initially be calculated based on:

- a constant F evaluation
- with the inclusion of stochasticity in population and exploitation as well as assessment/advice error.
- SRRs (using all; Ricker, Beverton-Holt, Segmented)
  Uncertainty parameters used:
  - **Assessment error**
    sigmaF = 0.18
    sigmaSSB = 0.17
  - **Advice error**
    cvF = 0.37
    phiF = 0.83
    cvSSB = 0.29
    phiSSB = 0.82
  - **Biological parameters and selectivity**
    numAvgYrsB = 20 # Number of years for averaging biological parameters
    numAvgYrsS = 20 # Number of years for averaging selectivity

To ensure consistency between the precautionary and MSY frameworks, F_{msy} is not allowed to be above F_{pa} , i.e., F_{msy} is set to F_{pa} if this initial F_{msy} estimate is higher than F_{pa} .

3. Simulation 3. Get final F_{msy}

MSY $B_{trigger}$ should be selected to safeguard against an undesirable or unexpected low SSB when fishing at F_{msy} . The ICES MSY advice rule should be evaluated to check that the F_{msy} and MSY $B_{trigger}$ combination adheres to precautionary considerations; in the long term, $P(SSB<B_{lim}) < 5\%$

The evaluation includes:
- realistic assessment/advice error (see above)
- stochasticity in population biology and fishery exploitation.
- SRRs (using all; Ricker, Beverton-Holt, Segmented)

Review of: Adjustments of the SAM model configuration for Faroe cod and saithe (5b)

Two similar changes are suggested for the Faroe cod and saithe assessments.

- Use AR(1) covariance structure for both surveys.
- Use a separate variance parameter for each of the age groups in the two surveys

It could be interesting to see each of the two suggested model changes applied alone to judge which is more important.

AIC and retrospective summary (Mohn's rho) are listed for 8 models for cod and 5 models for saithe, but only the models SPALLY and MOD0 are described. The remaining models are not mentioned in the text, or even defined. Hence it is impossible to evaluate them.

Using the AR(1) structure for both surveys appears to be an improvement, as the residual diagnostics improves by reducing the yearly systematic residual pattern for the surveys for both cod and saithe — especially for the last year of the spring survey. It also seems consistent to use a similar covariance structure for the two surveys. (Was it attempted for the catches also?) The corresponding correlation parameters (transfIRARdist) are estimated to be similar for the two cod surveys, but different for two saithe surveys, which is a little unexpected, but both estimates corresponds to positive un-transformed correlations (0.86 for the spring survey and 0.65 for the summer survey for neighboring age groups), which are within a previously seen range.

Using a separate variance parameter for every single age group for each survey is a fairly unconventional setting. The normal procedure is to use relatively few variance parameters, and use same variance parameters where possible. Estimating that many variance parameters can make the estimation unstable and the estimates can become very sensitive to outlying observations. It is obvious from the estimates that some of the variance parameters could be shared across age groups (e.g. for cod `logSdLogObs_3`≈-0.67 and `logSdLogObs_4`≈-0.64, both with standard deviations of 0.17). It also seems in great contrast to using only a single variance parameter (per stock) for the catches-at-age. Having more variance parameters than strictly needed is not necessarily a problem, as long as enough data is available to inform the model, but extra care should be taken to ensure that the model is properly identifiable and converging in all runs. A small simulation study could be helpful in accessing if the model is reliably converging. From the diagnostics provided it appears to be converging, but possibly the green retro line for cod, which changes to be far outside the confidence region when all other retro lines are fairly unchanged from the spally run, could indicate convergence issues.

From the residual plot of the cod catches-at-age it appears that the oldest age group have larger variance than the other age groups, and hence a separate variance parameter for this age group could be considered.

The spring index observations for cod age group 1 has a 7 observations (about a third) which are -7 on logarithmic scale. These are clearly outliers and originating from an arbitrary setting a low number (0.001) instead of missing observations. It should be considered if a better solution could be found (e.g. coding as missing or leaving out the age group)

The AIC may indicate a larger than justified difference between the two configurations, because the added variance parameters allow the model to better accommodate the outlying/artificial observations. In terms of model performance and estimated time series of interest the differences compared to the spally assessment are minor.

Overall the model appears to be configured such that the quality of the assessment is sufficient to be the basis for scientific advice.