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Exploration of the southern bluefin tuna (SBT) operating model and preliminary constant catch projections: CCSBT Operating Model & Management Procedure Technical Meeting, 13-17 July, 2009

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Introduction

In order to decide on the input data and final structure of the southern bluefin tuna (SBT) operating model (OM) to be used at the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) Scientific Committee (SC) meeting in September 2009, an Operating Model and Management Procedure Technical Meeting is to be held in July 2009. The focus of the meeting will be refining the OM for use in scenario modelling to assess the likely state of the stock and the implications of different levels of constant catches in the short-term. This paper focuses on a subset of the robustness trials identified at the Stock Assessment Group (SAG) technical meeting held in September 2008. A comprehensive examination of the reference set and robustness trials was not possible prior to the workshop. In addition to the robustness trials identified by the SAG we considered some additional issues, and comment on the effect of these parameterisations in terms of the fit to the various data inputs and significant differences to the current reference set and grid specification. Further work will be required at the OM meeting to assess: i) the new likelihood functions for the 1990s tagging data and incorporation of the scientific aerial survey into the reference set; ii) the need to refine the final set of robustness trials to be considered by the SAG and SC; and iii) specify the details of the performance statistics to be reported for the constant catch projections to be run for consideration by the SC.

SAG 2008

The 2008 meeting of the SAG agreed on a base case OM and grid to be used for conditioning the OM in 2009, though it was noted that inter-sessional work may lead to the refining of both. It was agreed that the base case model would be:

- *LL1* overcatch scenario based on Case 1 of the market review report.
- Surface fishery overcatch scenario of 20%.
- *CPUE* scenario *S* = 25% (25% of unreported catch attributed to *LL1* reported effort).
- *CPUE* data up to and including 2006.
- Lower bound on *CPUE* CV=0.20.
- OM fitting to the aerial survey with selectivity 0.5/1/1 for ages 2/3/4.
- *LL1* selectivity blocks changed in 2006 and 2007, and every 4 years prior to that with CV = 0.5.
- *LL2* selectivity blocks: pre 2002, 2002-2005, 2006-2007.
- Other assumptions retained as in previous OM.

The specification of axes for the new uncertainty grid used for projections is as in Table 1.

Table 1: The grid as agreed at SAG 2008.

	Levels	Cumul N	Values	Prior	Simulation Weights
Steepness (h)	3	3	0.385, 0.55, 0.73	0.2, 0.6, 0.2	prior
M0	3	9	0.3, 0.4, 0.5	uniform	prior
M10	3	27	0.07, 0.1, 0.14	uniform	prior
Omega	2	54	0.75, 1	0.4, 0.6	prior
CPUE	2	108		uniform	prior
q age-range	2	216	4-18, 8-12	0.67, 0.33	prior
Sample size	2	432	SQRT, ORIG.5	uniform	prior

The following robustness trials were also agreed at SAG 2008:

1. Effects of overcatch on *CPUE*: S = 50% and S = 75%.
2. *LL1* overcatch scenario based on Case 2 of Market Report.
3. Projected recruitment deviates uncorrelated to historical estimates from conditioning.
4. Include troll survey data.
5. Truncate *CPUE* series in 1992.
6. Use 5 historical CPUE series (i.e. incorporate 3 more series in addition to w.5 and w.8).
7. Break *CPUE* into two time series, the second starting in 1986.
8. Use likelihood-based weights for M0, M10 and ω for grid integration.
9. Increase the CV on *CPUE* to 0.30 and set the additional process error estimated for the aerial survey (${}_{aerial}\tau$) to 0.

Robustness trials

All runs of the OM were made using the code provided on 26 June 2009 with data included from the data submission in May 2009. As well as running the base case model, robustness trials, some as suggested by the SAG, as well as additional trials, were conducted. The additional trials focussed on the differences the new tag likelihood made on the output of the model. As the OM appeared to be sensitive to the choice of likelihood model for the tagging, we were interested in the effect of down weighting the tagging data. In order to investigate this, we considered the extreme case of setting the negative log-likelihood component for the tagging to zero, while also comparing to the old tagging model. The base case OM was run using the code containing the new tag likelihood (sbtmod22). Each of the robustness trials have been described in terms of differences from the base case.

The robustness trials investigated were:

1. Effects of overcatch on *CPUE*; S = 50% and S = 75%. (This is robustness trial 1 as outlined from SAG 2008).
2. Effects of overcatch on *CPUE*; S = 0%.
3. Increase the CV on *CPUE* from 0.20 to 0.30 and set the additional process error estimated for the aerial survey (τ_{aerial}) to 0. (This is robustness trial 9 as outlined from SAG 2008).
4. Use likelihood-based weights for M0, M10 and ω for grid integration. (This is robustness trial 8 as outlined from SAG 2008).
5. Use old tag likelihood.
6. Use old tag likelihood with likelihood-based weights for M0, M10 and ω for grid integration.
7. Set tag likelihood component to zero.

Applying the previous version of the model (without the correction in the aerial survey likelihood component), further robustness trials were carried out, but these were not able to be re-run before the meeting. Using the previous code we investigated (in addition to the above):

1. *LL1* overcatch scenario based on Case 2 of Market Report. (This is robustness trial 2 as outlined from SAG 2008).
2. Truncate *CPUE* series in 1992. (This is robustness trial 5 as outlined from SAG 2008).
3. Break *CPUE* into two time series, the second starting in 1986. (This is robustness trial 7 as outlined from SAG 2008).
4. Include troll survey data. (This is robustness trial 4 as outlined from SAG 2008).

Constant catch projections

It was agreed at SAG 2008 that management advice in 2009 would be based on constant catch projections from the reconditioned OM, in contrast to a fully developed management procedure (MP) (CCSBT SC meeting report 2008), and an evaluation of current stock status and recent recruitment based on indicators. The SAG agreed to 5 levels of future constant catch as an initial basis for the provision of management advice:

- Use the current TAC of 11810 t
- Current TAC + 2000 t
- Current TAC – 2000 t
- Current TAC + 4000 t
- Current TAC – 4000 t

In addition it was agreed that the following reference points would be used to report the results of constant catch projections. These reference points were:

- Probability of B2014 > B2004
- Probability of B2014 > B2008
- Medians and lower 10th percentiles of the ratios B2014/B2004, B2014/B2008. B2022/B2004, B2022/B2008
- Medians of B2008/1980, B2008/B1931

where B is spawning biomass.

At the CCSBT Strategy and Fisheries Management Working Group meeting in April 2009, it was requested that the 30th percentile be included for the above reference points where relevant and that B2020/B2010 and B2025/B2010 also be included. The Working Group also requested an additional constant catch projection of zero global catch be examined to determine how quickly the stock may rebuild in the absence of fishing.

All constant catch projections were made using the 7 July 2009 version of the code.

Results

Detailed diagnostics and output for all robustness trials are not presented. Results are only presented where significant findings or observations that may prove useful in discussing changes to the OM have been observed. As the major change that has been made to the OM since SAG 2008 has been the new tag likelihood model, the results focus on the difference this new tag likelihood has made in terms of plausibility of the grid and biomass projections.

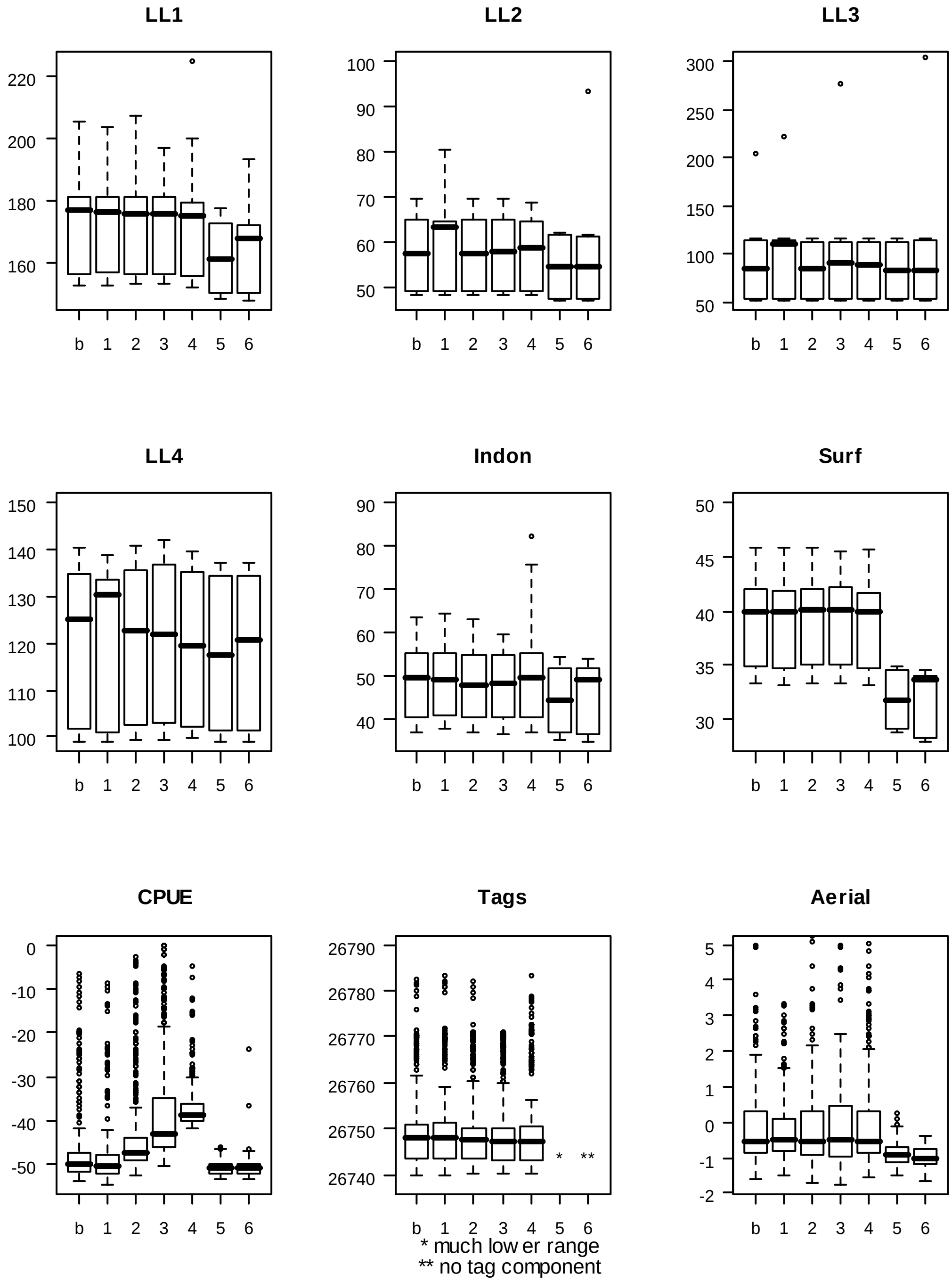
Negative log-likelihood for main components

Figure 1 shows the negative log-likelihood (NLL) ranges for the main components of the OM for the different trials run using the OM. The main components of the OM are the length frequency data for the four fisheries (LL1-4), the age composition data from the Indonesian and surface fisheries, and the CPUE series, tagging data and scientific aerial survey data. The NLL values for the tag component are much greater with the new tag likelihood than when using the old tag likelihood. As a result, the range for the tag component of the model using the old tag likelihood does not appear in the plot. It should be noted though, that NLL ranges are only comparable among like models, so comparing the NLL ranges between the OM with the new tag likelihood to the OM with the old tag likelihood is not appropriate.

The most evident difference in NLL ranges for the different scenarios is seen in the plot for the CPUE component. As has been noted in previous SAG meeting notes, the median NLL values for the CPUE component for the scenarios where there is 50% and 75% scaling of the CPUE are noticeably higher than for the base case. This suggests the OM does not fit as well to these high scalings of CPUE. The base case and 0% scaling of CPUE scenarios are similar in range and median values.

It was noted that there were skewed median values for the robustness trial with 0% scaling of CPUE for the LL2 and LL3 components of the model. This is also the case when setting the tag NLL component to zero for the surface fishery component. This seems to suggest that these values reached some bound in the estimation process.

In all the other main components of the OM, there were no major differences. For the surface fishery age composition data, the OM using the old tag likelihood and the OM with the tag NLL set to 0 have a lower NLL range than the other scenarios, but these are essentially different models to the others and so this difference is not directly comparable.



Negative log-likelihood ranges for the main components of the conditioned OM

Figure 1: Boxplots of the negative log-likelihood ranges for the main components of the OM. “b” is the base case model, “1” is no scaling of the CPUE, “2” is 50% scaling of CPUE, “3” is 75% scaling of CPUE, “4” is the OM with the CV on CPUE increased to 0.3 and the additional process error estimated for the aerial survey (τ_{aerial}) set to 0, “5” is the OM using the old tag likelihood, and “6” is the OM with the tag NLL set to 0. *For “5” the median NLL is 7.2 with a minimum of 4.9 and a maximum of 21.6.

Convergence issues

Inter-sessional work highlighted that there may be an issue with convergence when using the OM with the new tag likelihood as the maximum gradients for some grid cells were greater than 10. Work by other scientists showed that most of the cases with high maximum gradients also had high objective function values too. Table 2 shows the number of grid cells with the maximum gradient greater than 0.2, 10 and 100 for each of the different scenarios. The counts were split over the two sample size options; "ORIG.5" and "sqrt". Convergence tends to be more of an issue for the "ORIG.5" sample size option and appears to be increasingly harder to achieve with higher scalings of the CPUE.

Figure 2 shows plots of the relative difference in the value of the objective function, aggregated by M0 and M10 levels, for all 216 grid cells using sample size option "ORIG.5" for the trial where the CPUE is scaled by 75%. This plot shows that the runs where the objective function was high (and so were more likely to have failed to converge) tends to be characterised by having a high M0 and high M10. This suggests that the data seems to not support this combination of M0 and M10.

Table 2: The number of grid cells with the maximum gradient greater than 0.2, 10 and 100 for each of the trials with numbers grouped depending on the sample size options: "ORIG.5" and "sqrt".

Convergence Max gradient	ORIG.5 >0.2	>10	>100	sqrt >0.2	>10	>100
Base	34	26	21	13	8	3
CPUE S=0%	34	25	21	8	4	0
CPUE S=50%	42	36	30	9	3	1
CPUE S=75%	59	50	44	11	5	1
CV 0.3 +tau=0	26	6	2	12	3	0
Tag NLL = 0	2	1	1	6	3	1
Old Tag LLH	9	0	0	4	0	0

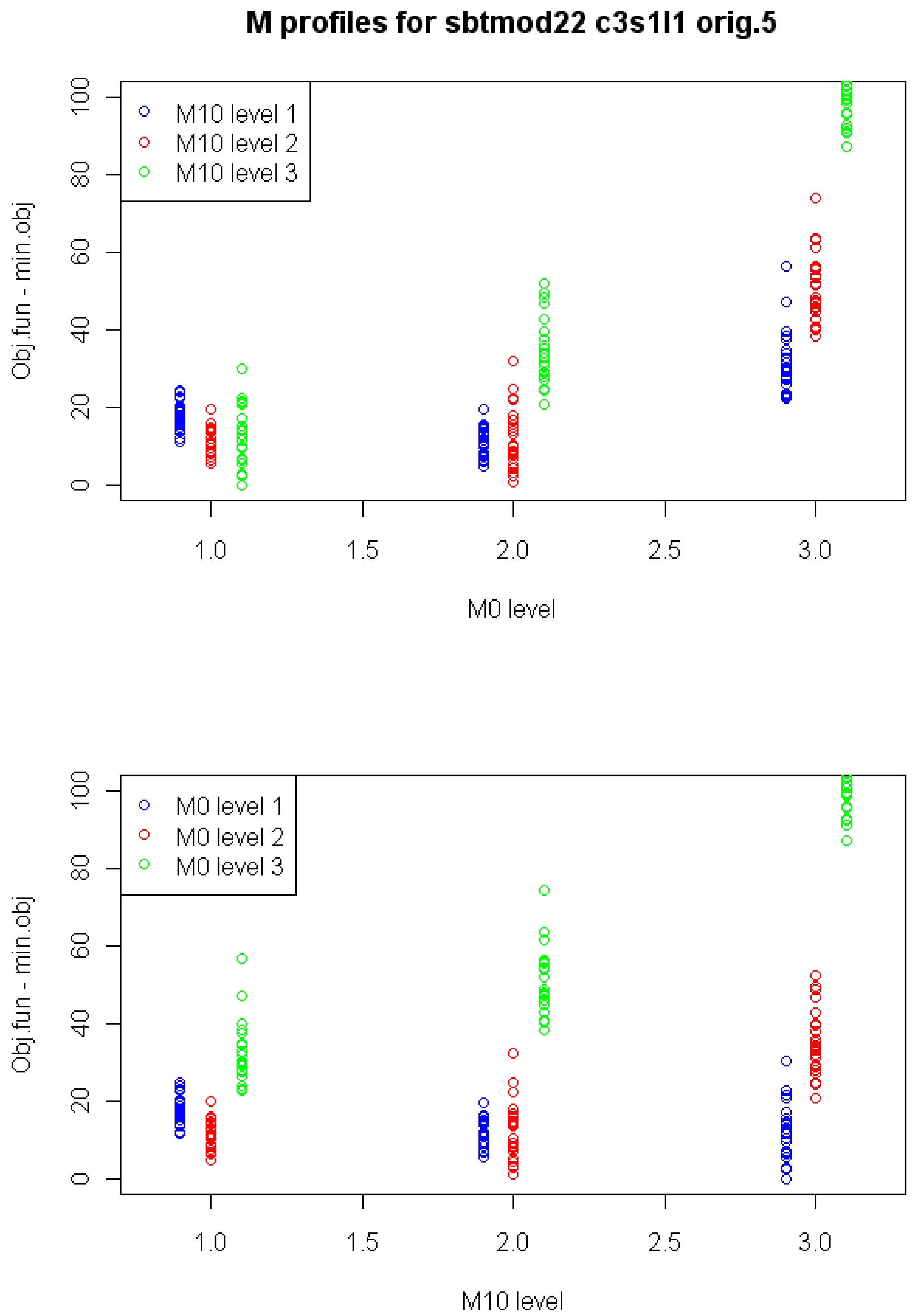


Figure 2: Plots of the relative difference in the value of the objective function, aggregated by M0 and M10 levels, for all 216 grid cells using sample size option "ORIG.5" for the trial where CPUE is scaled by 75%.

Using likelihood based weights for M0, M10 and Omega for grid integration

Figure 3 shows the weighting of grid cell results in the projection when using the agreed grid from SAG 2008 where simulation weights have been set equal to the prior for all grid axes. The plot shows good coverage of the grid as was the intention by using the priors rather than posteriors, with all grid cells represented in the projections.

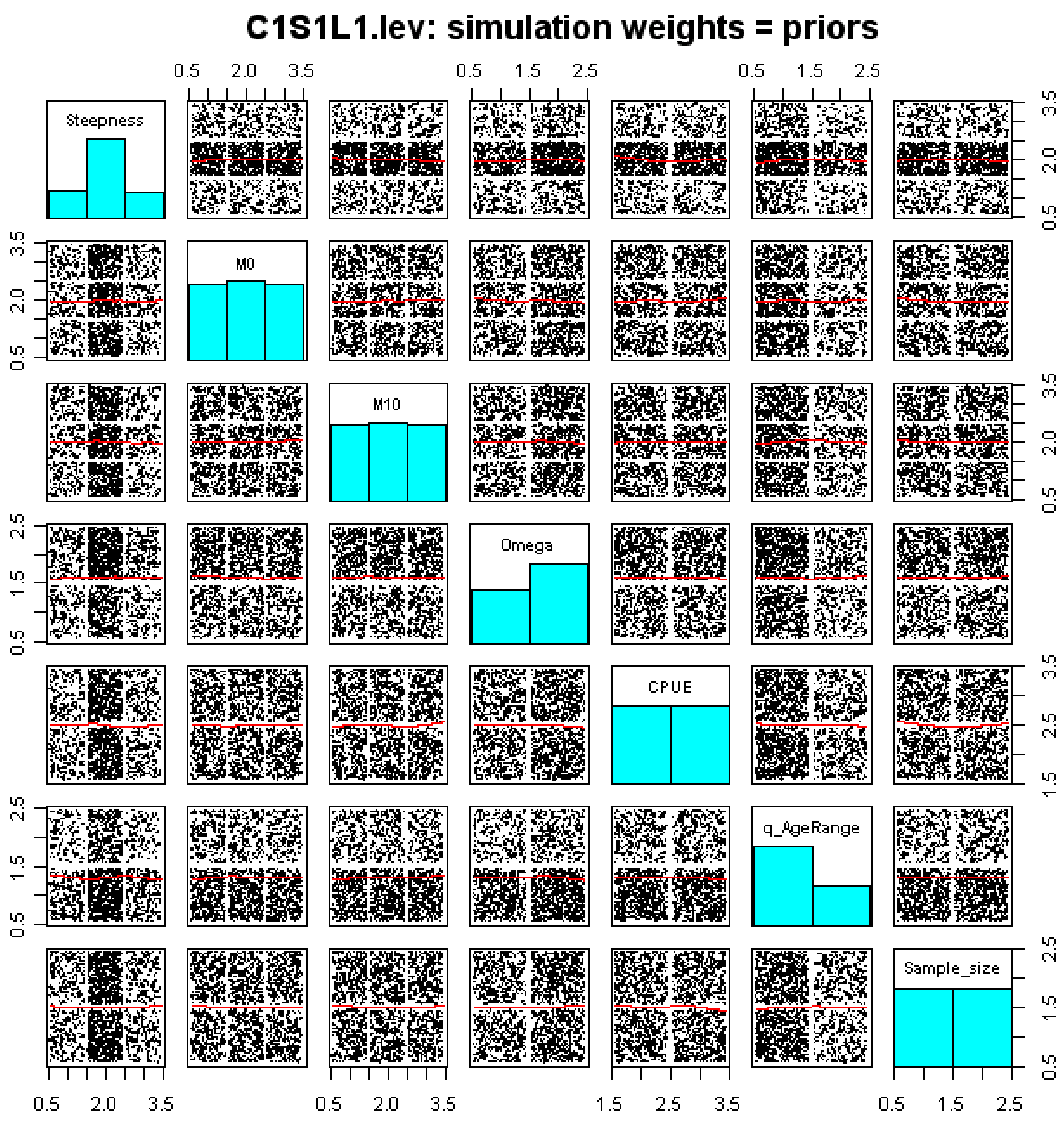


Figure 3: Pairs plot of the ".lev" file from the base case OM with the new tag likelihood and simulation weights equal to the priors, indicating the relative weighting of grid axis values in the projection results.

Figure 4 uses the base case OM with the old tag likelihood where the simulation weights for M0, M10 and Omega have been set to the posterior weights. At SAG 2008 it was noted that "use of likelihood based weights in grid integration gave very little weight to the high and mid values of M0, low values of M10 and Omega=0.75”. This is still the case with another year of data added to the OM when the old tag likelihood is used.

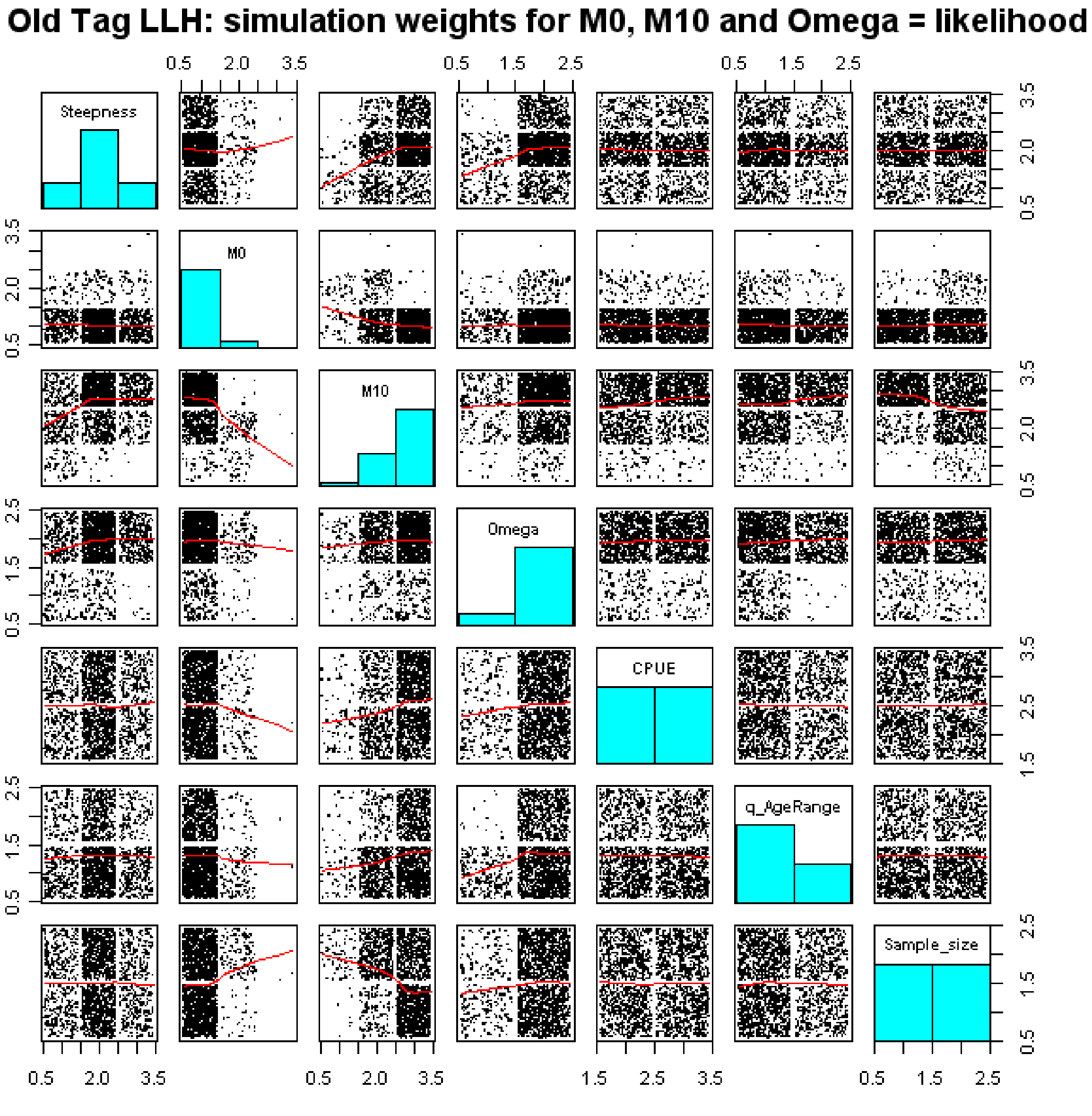


Figure 4: Pairs plot of the “.lev” file from the base case OM with the old tag likelihood and simulation weights of M0, M10 and Omega equal to the posteriors, indicating the relative weighting of grid axis values in the projection results.

Figure 5 uses the base case OM with the new tag likelihood where the simulation weights for M0, M10 and Omega have been set to the posterior weights. The high value of M0 is not sampled at all, but the low and mid values of M0 have more even weightings than when using the old tag likelihood than what was seen in 2008. As in 2008, low values of M10 are given less weight than the high values, but in the case of the Omega value, the lower value of 0.75 is slightly preferred over the higher.

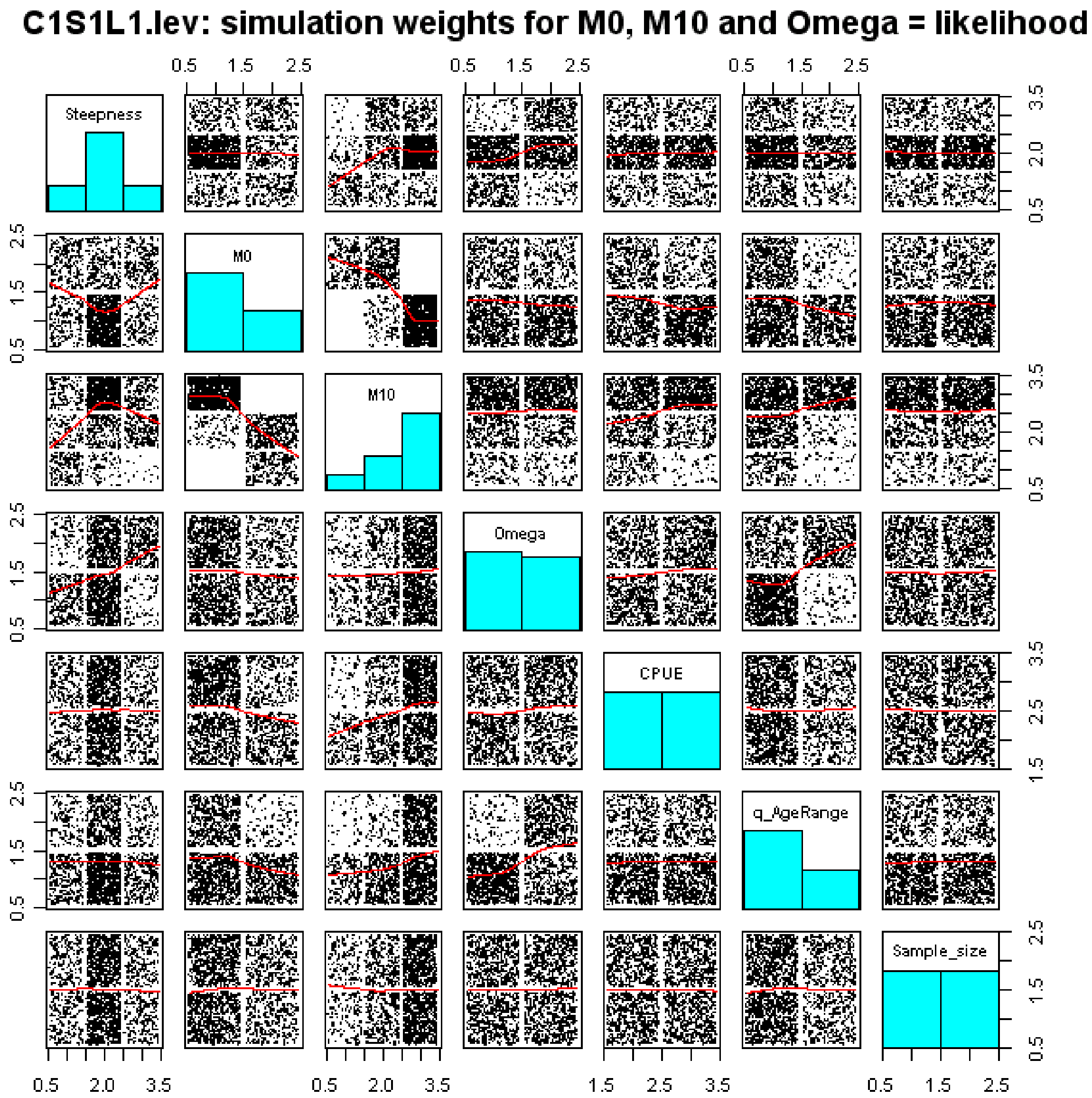


Figure 5: Pairs plot of the ".lev" file from the base case OM with the new tag likelihood and simulation weights of M0, M10 and Omega equal to the posteriors, indicating the relative weighting of grid axis values in the projection results.

Model fits

Notation for individual grid cells, e.g. c1s1l1ORIG.5_h1m1M1O1C2a1:

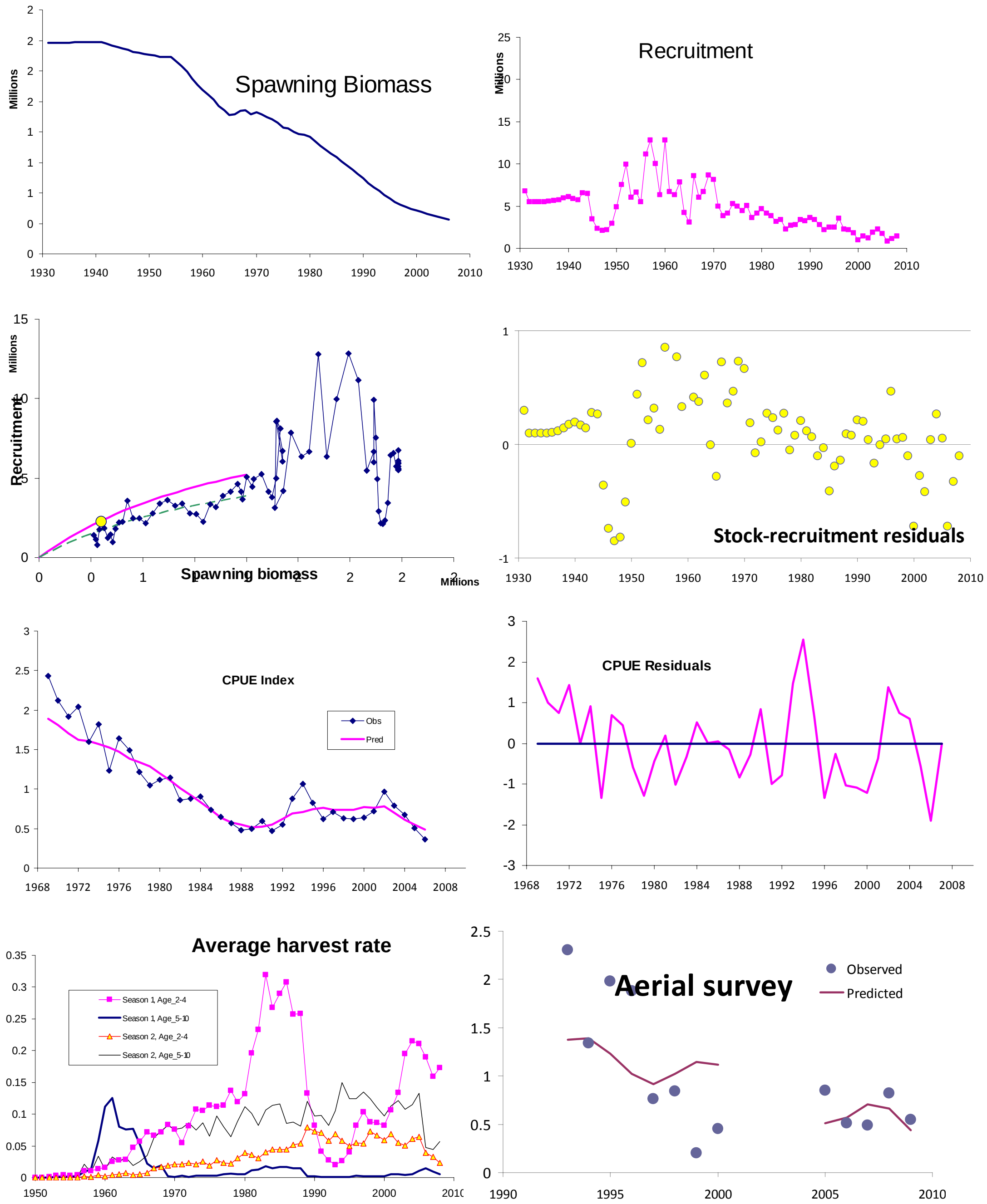
- c1s1l1ORIG.5 relates to the base case (i.e. scaling of CPUE of 25% (c1), surface fishery age composition scaled up by 20% (s1), lagged market anomaly catches (l1), and the 'original' sample size option for age and size data halved (ORIG.5).
- h1m1M1O1C2a1 relates to the value of each grid entry: h, m, M and O are the parameters steepness, mortality M0, mortality M10 and Omega; C is the CPUE series chosen and a is the catchability age range. The digits following relate to the value from Table 1 used, with 1 denoting the first in the value list, 2 the second and 3 the third.

A ‘base case’ grid cell was chosen to be c1s1l1ORIG.5_h1m1M1O1C2a1, using the base case scenario with the ORIG.5 sample size option, and the lower values of the 4 parameters (h, m0, M10 and Omega). This choice was arbitrary, but provided a case of reasonable fits to the data. The GridView results are given in the following figures (a)-(h). The ‘base case’ is illustrated in (a), the impact of changes in mortality in (b), the impact of increased steepness in (c), and of increased Omega in (d). These GridView results were compared with the ‘base case’ grid cell (a). Further, the case of not including tagging is given in (e), or of including the old tagging model in (f). Also, the case of increasing the CPUE CV and setting τ_{aerial} to zero is considered in (g). Finally, the impact of selecting the upper limits of the four grid parameters (h, M0, M10 and Omega) is examined in (h).

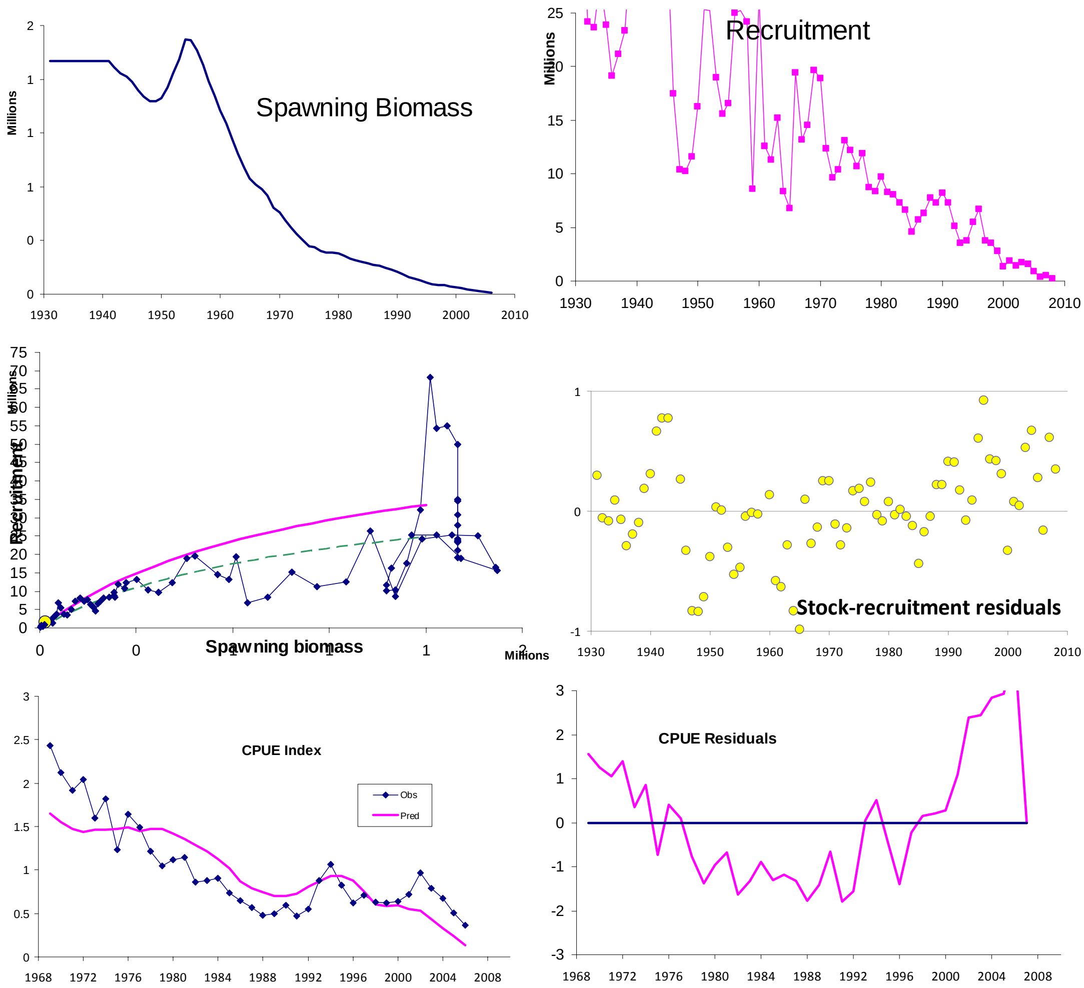
It should be noted that, in all cases considered, the fits to length and age data (with the exception of the fishery LL3) were good and changed only in minor ways between the grid cells considered. The poor fits for LL3 could derive from selectivity, which changed significantly for that fishery in 1975.

Further, the combination of high M0 and M10 values led, in general, to heavily autocorrelated S-R and CPUE residuals. This agrees with the results of runs carried out with posterior simulation weights for these parameters, where application of this weighting led to an exclusion of high values for M0 (see Figure 5) and thus a combination of high values for both mortalities not being incorporated into the projections.

(a) base_c1s1l1ORIG.5_h1m1M1O1C2a1 – this case is used as the 'base case' grid cell with which other cells are compared



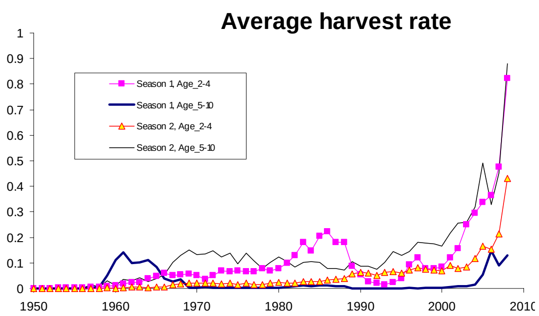
(b) c1s1l1ORIG.5_h1**m3M3**O1C2a1 – case with increased mortality

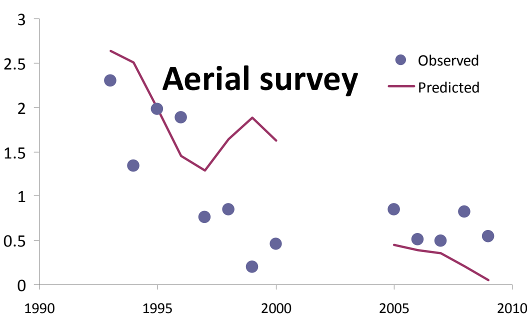


Note (when compared with the ‘base case’ grid cell)

- very low recent spawning biomass
- very high early recruitment – very low recent levels
- highly autocorrelated CPUE residuals
- poor CPUE fit
- autocorrelated S-R residuals

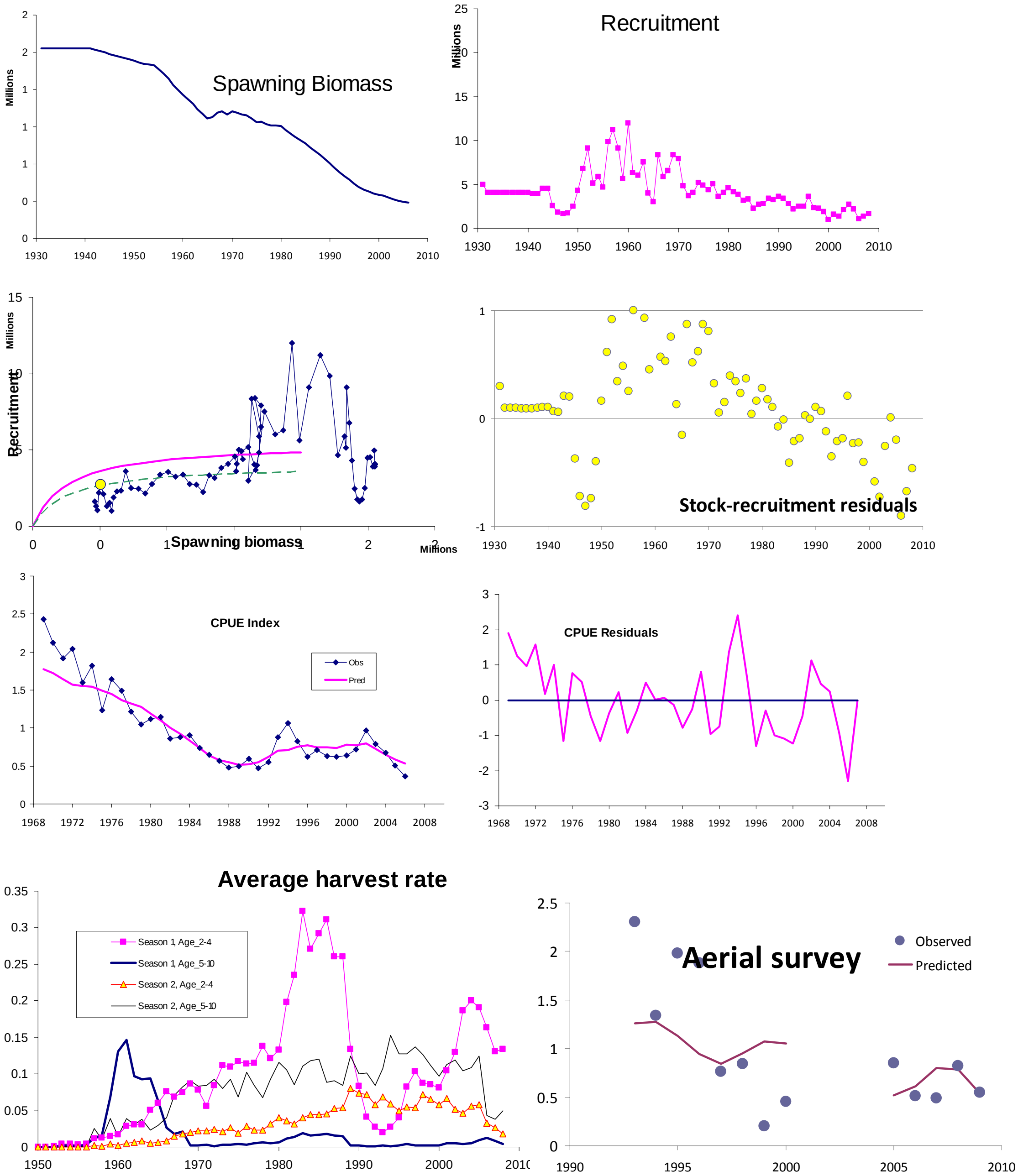
There were also very high model predictions of F for this grid cell, compared with the ‘base case’ cell.





Further, grid cells for an increase in M0 alone and M10 alone were considered. For an increase in M0 (c1s1l1ORIG.5_h1m3M1O1C2a1) CPUE residuals became more correlated and recent spawning biomass decreased. For an increase in M10 (c1s1l1ORIG.5_h1m1M3O1C2a1), these changes were more pronounced, but not as pronounced as in the case when both M0 and M10 were increased (see figures).

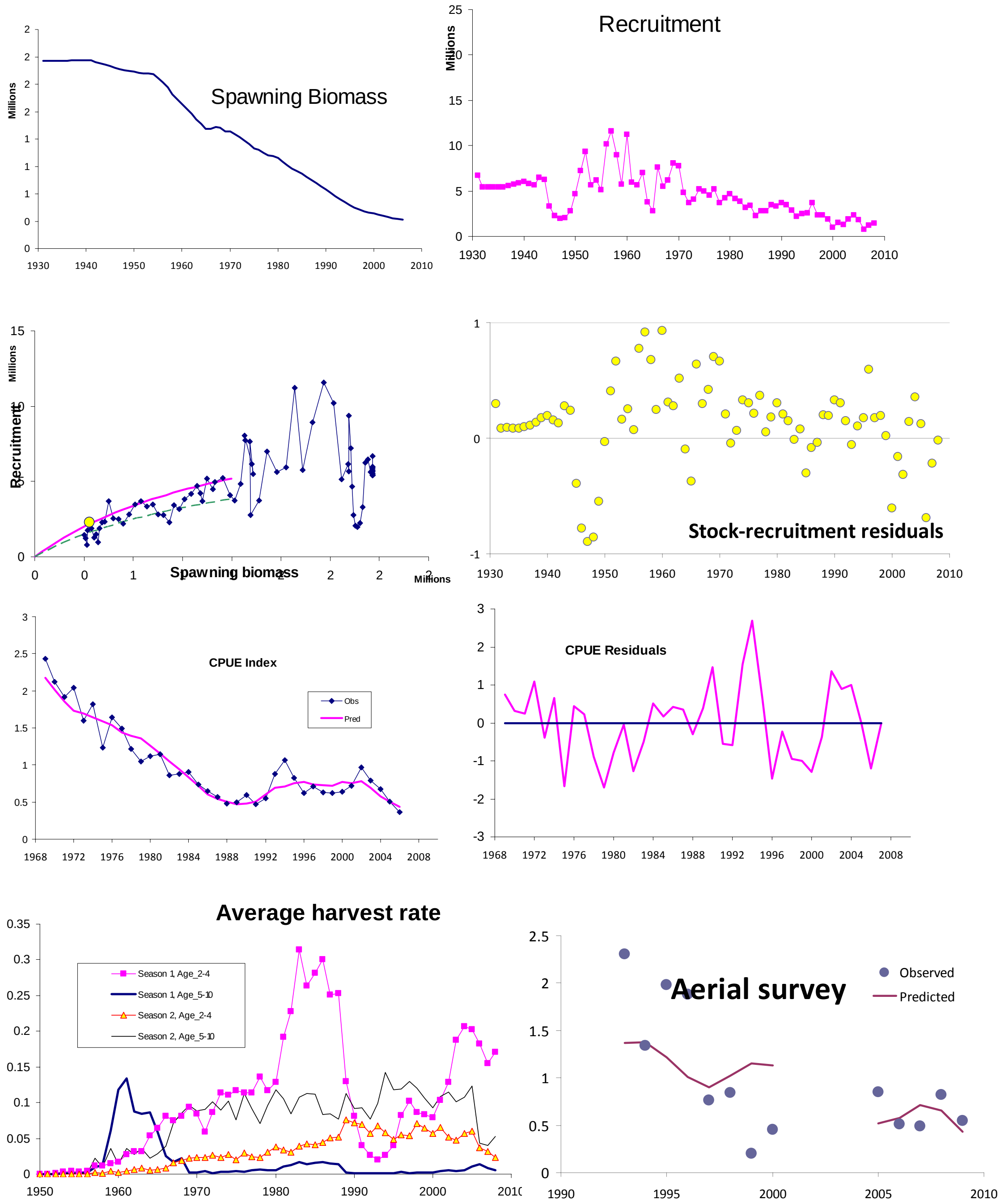
(c) c1s1l1ORIG.5_**h3**m1M1O1C2a1 – case of an increased steepness parameter for stock recruitment



Note (when compared with the 'base case' grid cell)

- autocorrelation in the S-R residuals
- poor fit in the S-R relationship

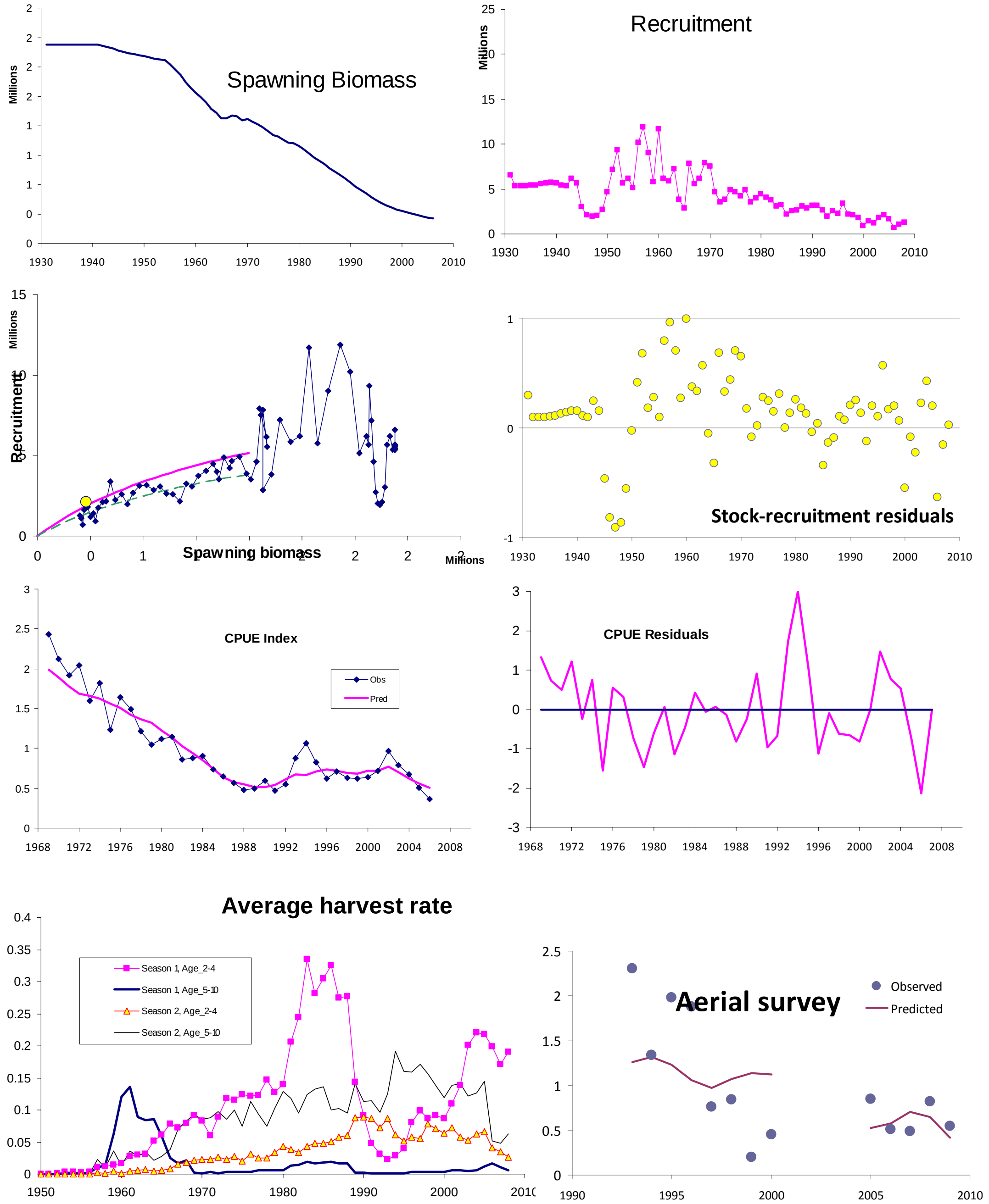
(d) c1s1l1ORIG.5_h1m1M1**O2**C2a1 – case of increased Omega



Note (when compared with the 'base case' grid cell)

- improved CPUE fit
- slightly more biased S-R residuals than 'base case' grid cell

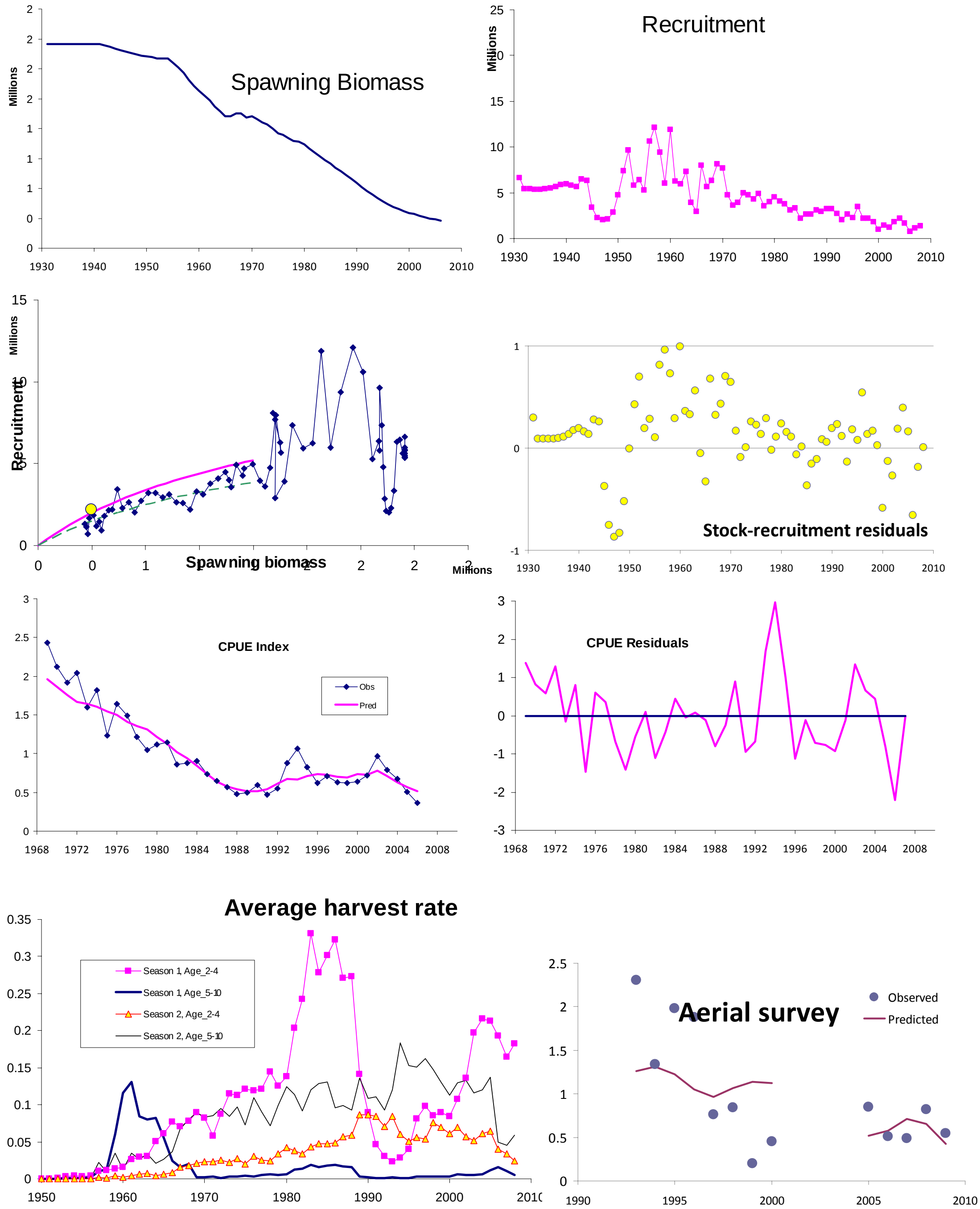
(e) **Tag0**_c1s1l1ORIG.5_h1m1M1O1C2a1 – excluding the tagging model



Note (when compared with the 'base case' grid cell)

- slightly better fit to CPUE
- slightly more biased S-R residuals

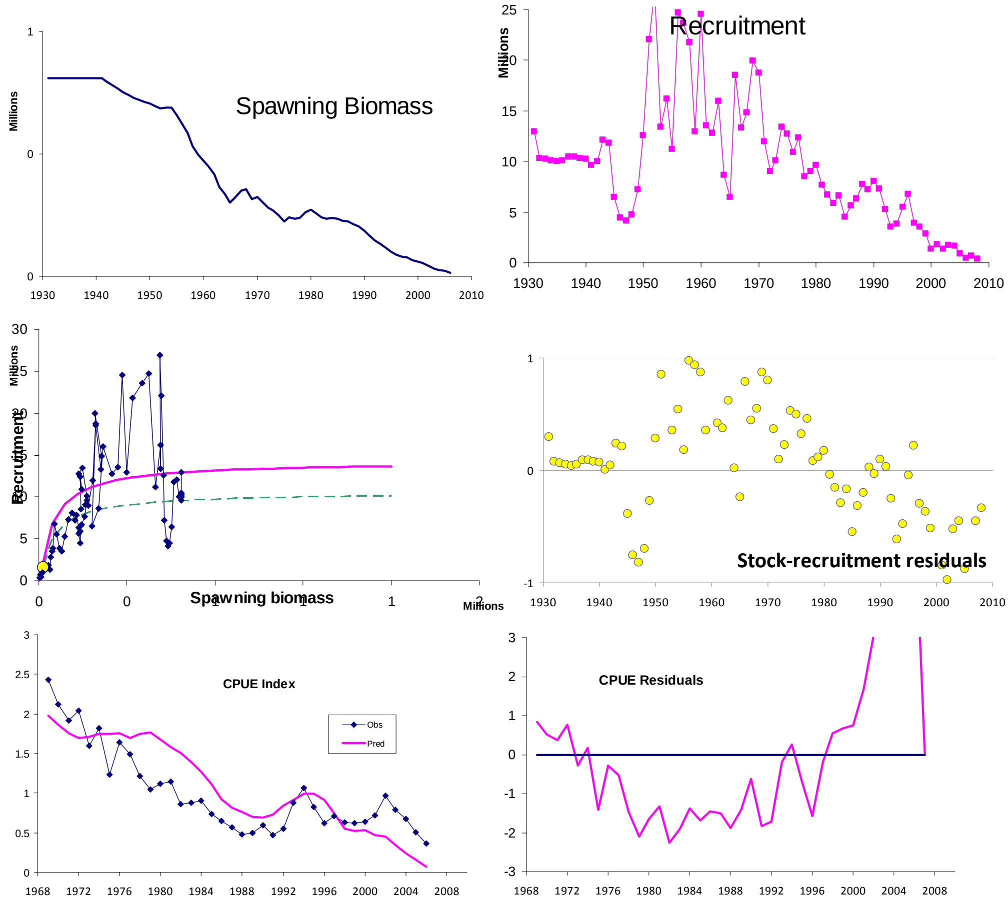
(f) **oldTagLLH**_c1s1l1ORIG.5_h1m1M1O1C2a1 – case of old tagging model



Note

- there is negligible change when compared with the 'base case' grid cell.

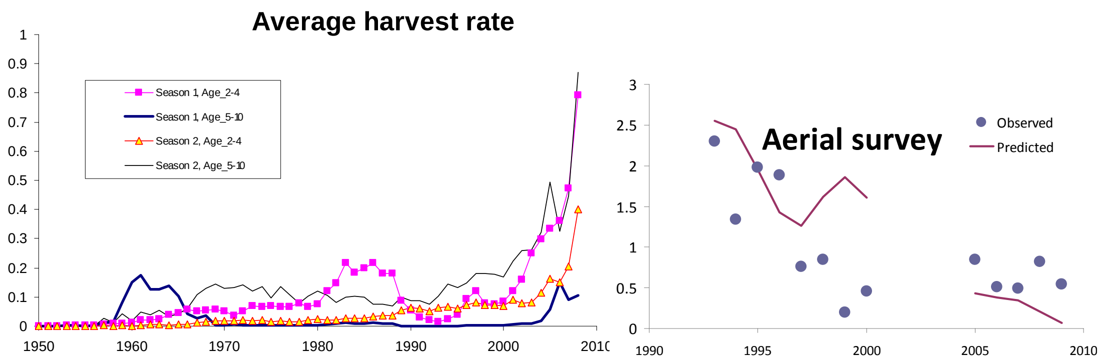
(g) c1s1l1ORIG.5_**h3m3M3O2**C2a1 – upper extremes of the 4 parameter values (h, M0, M10 and Omega)



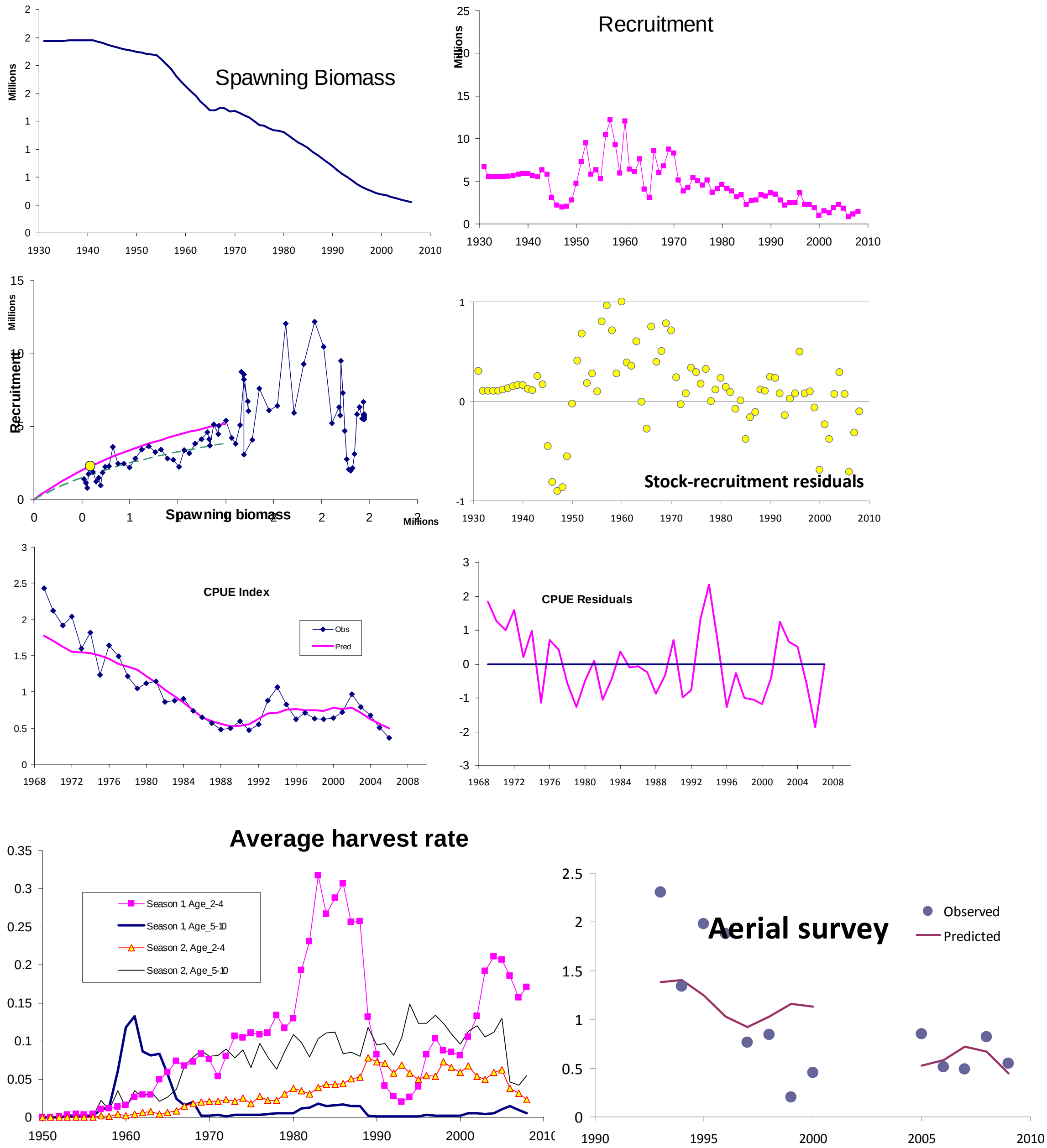
Note (when compared with the 'base case' grid cell)

- very low recent spawning biomass
- high recruitment (1950-1970)
- autocorrelated S-R residulas
- highly autocorrelated CPUE residuals
- poor fit to CPUE

Also, very high estimates of F in recent years compared with the 'base case' grid cell.



(h) c1s1l1ORIG.5_**cv0.3_tau0**_h1m1M1O1C2a1 – decreasing fit to CPUE by increasing CV from 0.2 to 0.3, and setting τ_{aerial} to zero



Constant catch projections

Constant catch projections were run for each level of future total catch using the base case incorporating the new tag likelihood. The plots show the results of 50 year projections for each of the six constant catch alternatives. Cases with different tagging models were considered to investigate the effect of the tagging data and its structure in the model on projection results, and thus management strategies. Projections, particularly long-term, should be treated with caution. For both long- and short-term projections, cohort data are available, although there is uncertainty concerning observations and process. For longer-term predictions, there is further uncertainty concerning, in particular, stock-recruitment for which there are no data. The purpose of including 50 year projections was to examine relative trends under different constant catch alternatives, and should be interpreted with these caveats in mind.

Base case (new tag likelihood)

The OM using the new tag likelihood suggests the current median spawning biomass is at 5% of unexploited spawning biomass.

Short-term projections of constant catches at, or above, the current TAC, indicate that:

- the probability that the median spawning biomass in 2014 will be lower than 2004 or 2008, is very high (ranging from 98% and 99%, respectively, for the case where the current TAC is used, up to 100% for both cases when the catch is 4000 t above TAC);
- there is more than 30% probability that the median spawning biomass in 2014 will be less than half of the estimate for 2004 or 2008 and a significant proportion of runs (>10%) declined to zero.

Short-term projections of constant catches of 2000 t or more, less than the current TAC indicate that:

- the probability that the median spawning biomass in 2014 will be lower than 2004 or 2008, is still high despite lower catch (ranging from 62% and 32%, respectively in the zero catch case, to 95% and 96% if the catch is 2000 t less than the TAC);
- for a constant catch of zero, there is a 50% chance that the median spawning biomass in 2014 will be greater than 92% of 2004 levels, and greater than 2008 levels.

TAC zero	10%	30%	50%
B2014/B2004	0.68	0.82	0.92
B2014/2008	0.89	0.99	1.09
B2022/B2004	0.94	1.30	1.70
B2022/B2008	1.23	1.62	2.07
B2022/B2010	1.37	1.83	2.32
B2025/B2010	1.58	2.22	2.90
B2008/B0	0.02	0.03	0.05
B2008/B1980	0.05	0.09	0.14
P(B2014>B2004)	0.38		
P(B2014>B2008)	0.68		

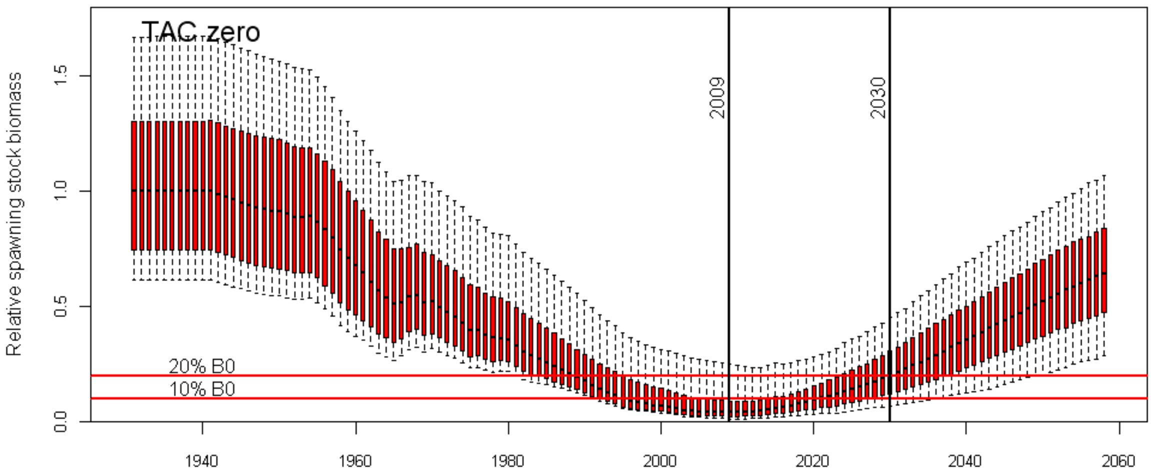
TAC Current	10%	30%	50%
B2014/B2004	0.00	0.40	0.59
B2014/2008	0.00	0.48	0.69
B2022/B2004	0.00	0.00	0.12
B2022/B2008	0.00	0.00	0.14
B2022/B2010	0.00	0.00	0.16
B2025/B2010	0.00	0.00	0.00
B2008/B0	0.02	0.03	0.05
B2008/B1980	0.05	0.09	0.14
P(B2014>B2004)	0.02		
P(B2014>B2008)	0.01		

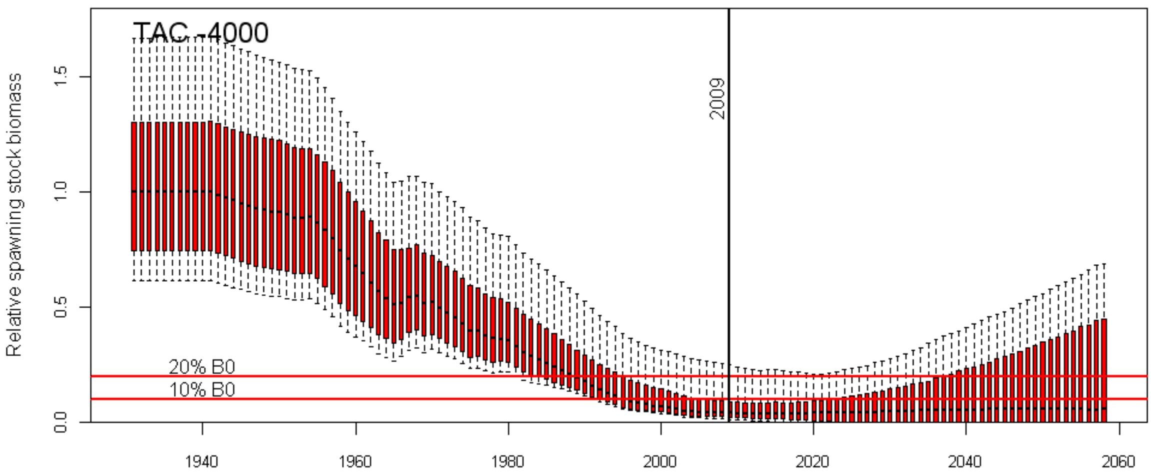
TAC -4000	10%	30%	50%
B2014/B2004	0.23	0.60	0.72
B2014/2008	0.32	0.74	0.83
B2022/B2004	0.00	0.29	0.65
B2022/B2008	0.00	0.36	0.75
B2022/B2010	0.00	0.41	0.83
B2025/B2010	0.00	0.24	0.84
B2008/B0	0.02	0.03	0.05
B2008/B1980	0.05	0.09	0.14
P(B2014>B2004)	0.09		
P(B2014>B2008)	0.09		

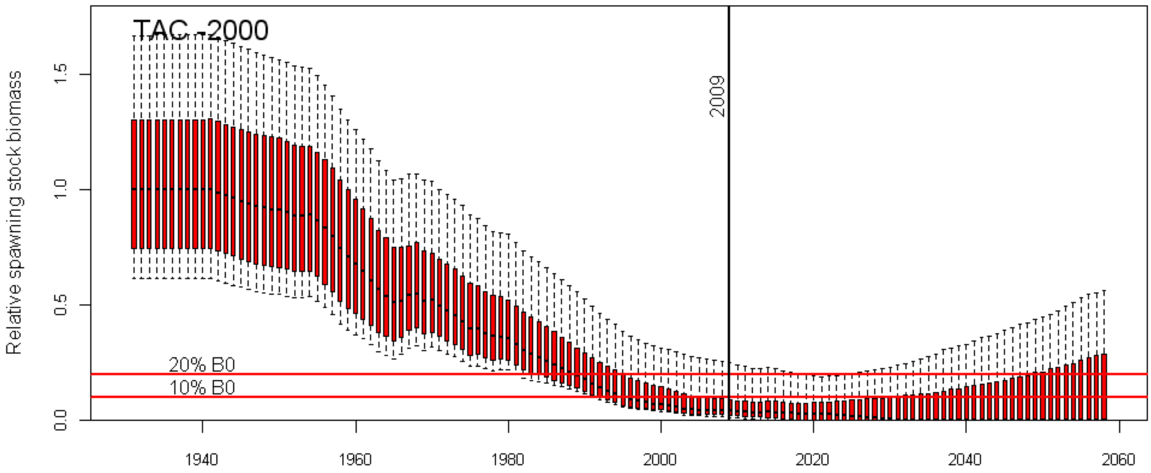
TAC +2000	10%	30%	50%
B2014/B2004	0.00	0.26	0.51
B2014/2008	0.00	0.30	0.59
B2022/B2004	0.00	0.00	0.00
B2022/B2008	0.00	0.00	0.00
B2022/B2010	0.00	0.00	0.00
B2025/B2010	0.00	0.00	0.00
B2008/B0	0.02	0.03	0.05
B2008/B1980	0.05	0.09	0.14
P(B2014>B2004)	0.01		
P(B2014>B2008)	0.00		

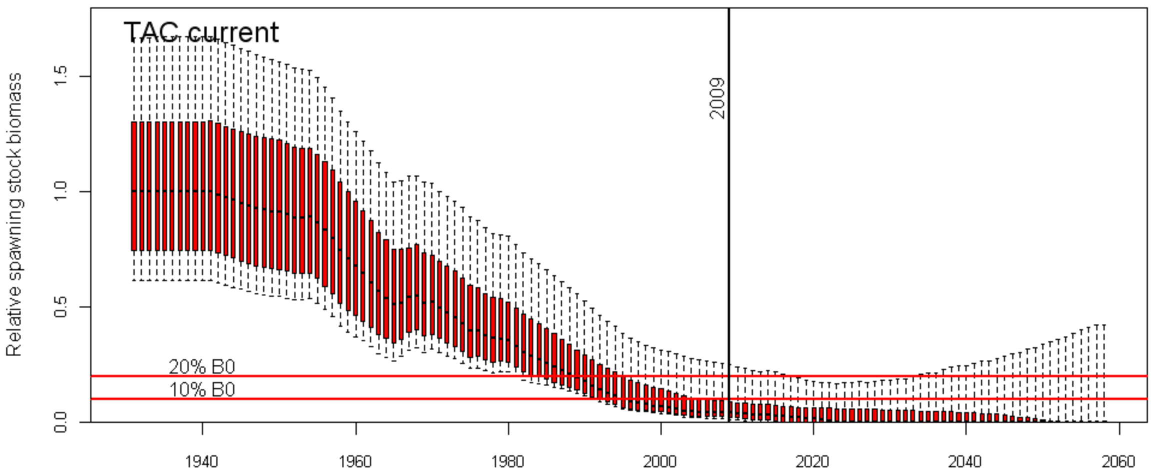
TAC -2000	10%	30%	50%
B2014/B2004	0.03	0.50	0.66
B2014/2008	0.04	0.62	0.76
B2022/B2004	0.00	0.00	0.40
B2022/B2008	0.00	0.00	0.46
B2022/B2010	0.00	0.00	0.52
B2025/B2010	0.00	0.00	0.39
B2008/B0	0.02	0.03	0.05
B2008/B1980	0.05	0.09	0.14
P(B2014>B2004)	0.05		
P(B2014>B2008)	0.04		

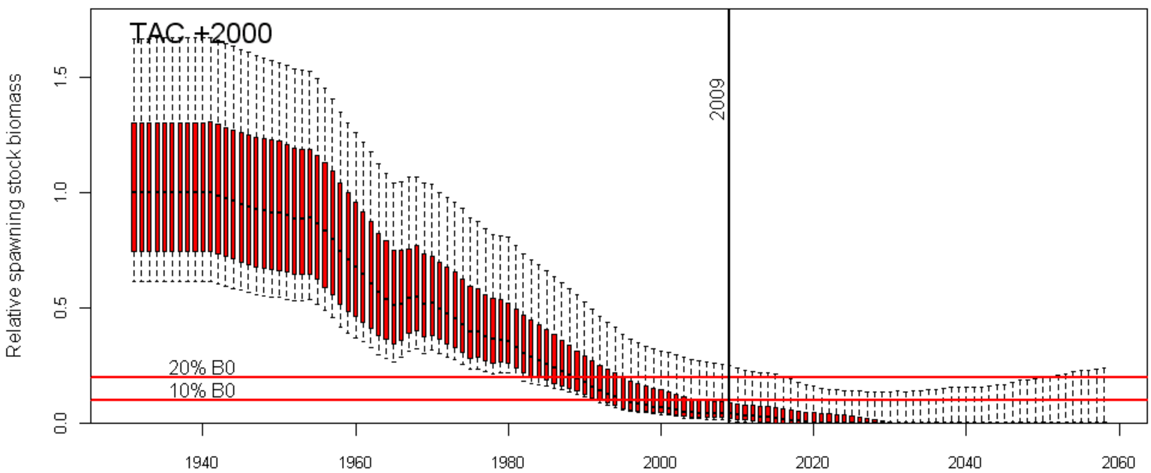
TAC +4000	10%	30%	50%
B2014/B2004	0.00	0.11	0.43
B2014/2008	0.00	0.13	0.49
B2022/B2004	0.00	0.00	0.00
B2022/B2008	0.00	0.00	0.00
B2022/B2010	0.00	0.00	0.00
B2025/B2010	0.00	0.00	0.00
B2008/B0	0.02	0.03	0.05
B2008/B1980	0.05	0.09	0.14
P(B2014>B2004)	0.00		
P(B2014>B2008)	0.00		

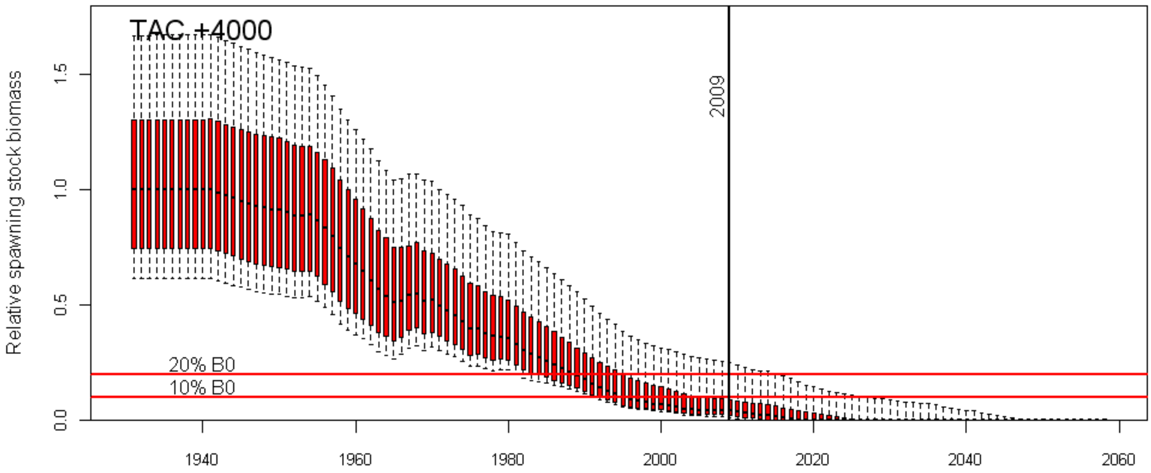





TAC -2000
2009
20% B0
10% B0
Relative spawning stock biomass
0.0
0.5
1.0
1.5
1940
1960
1980
2000
2020
2040
2060


TAC current
2009
20% B0
10% B0
Relative spawning stock biomass
0.0
0.5
1.0
1.5
1940
1960
1980
2000
2020
2040
2060


TAC +2000
2009
20% B0
10% B0
Relative spawning stock biomass
0.0
0.5
1.0
1.5
1940
1960
1980
2000
2020
2040
2060



Base case (old tag likelihood)

The OM using the old tag likelihood suggests the current median spawning biomass is at 7% of unexploited spawning biomass.

Short-term projections of constant catches at, or above, the current TAC, indicate that:

- the probability that the median spawning biomass in 2014 will be lower than 2004 or 2008, is very high (ranging from 89% and 94%, respectively, for the case where the current TAC is used, to 96% and 99% when the catch is 4000 t above TAC);
- for a constant catch at current TAC levels, there is a 50% chance that the median spawning biomass in 2014 will be greater than 75% of 2004 levels, and greater than 82% of 2008 levels.

Short-term projections of constant catches of 2000 t or more, less than the current TAC indicate that:

- the probability that the median spawning biomass in 2014 will be lower than 2004 or 2008, is still high for the cases where catch is 4000 t and 2000 t less than the current TAC (74% and 72%, respectively, in the minus 4000 t catch case, and 83% and 87%, in the minus 2000 t case);
- for a constant catch of zero, there is a 50% chance that the median spawning biomass in 2014 will be greater than 2004 levels, and a 70% chance that it is greater than 2008 levels.

TAC zero	10%	30%	50%
B2014/B2004	0.81	0.93	1.07
B2014/2008	0.97	1.05	1.16
B2022/B2004	1.19	1.52	1.95
B2022/B2008	1.34	1.72	2.12
B2022/B2010	1.42	1.81	2.18
B2025/B2010	1.64	2.18	2.73
B2008/B0	0.05	0.05	0.07
B2008/B1980	0.11	0.14	0.18
P(B2014>B2004)	0.59		
P(B2014>B2008)	0.82		

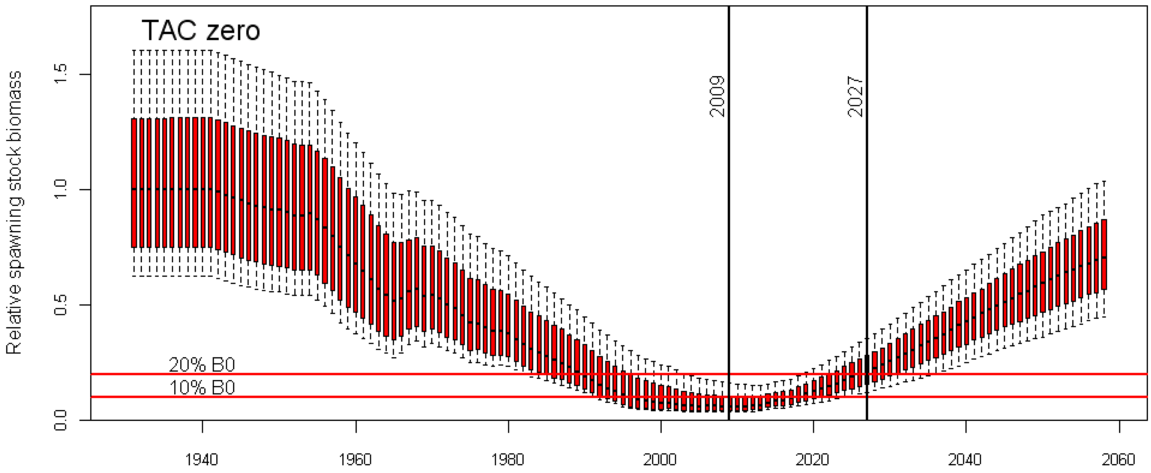
TAC Current	10%	30%	50%
B2014/B2004	0.57	0.68	0.75
B2014/2008	0.67	0.77	0.82
B2022/B2004	0.00	0.36	0.56
B2022/B2008	0.00	0.40	0.61
B2022/B2010	0.00	0.44	0.67
B2025/B2010	0.00	0.31	0.62
B2008/B0	0.05	0.05	0.07
B2008/B1980	0.11	0.14	0.18
P(B2014>B2004)	0.11		
P(B2014>B2008)	0.06		

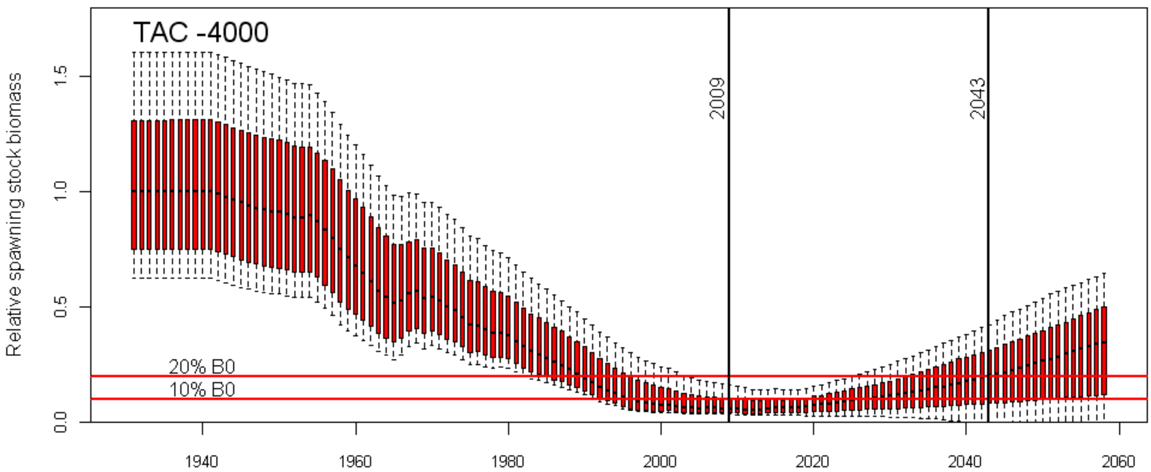
TAC -4000	10%	30%	50%
B2014/B2004	0.68	0.78	0.86
B2014/2008	0.82	0.88	0.93
B2022/B2004	0.52	0.76	0.97
B2022/B2008	0.58	0.86	1.06
B2022/B2010	0.64	0.93	1.14
B2025/B2010	0.60	1.00	1.31
B2008/B0	0.05	0.05	0.07
B2008/B1980	0.11	0.14	0.18
P(B2014>B2004)	0.26		
P(B2014>B2008)	0.28		

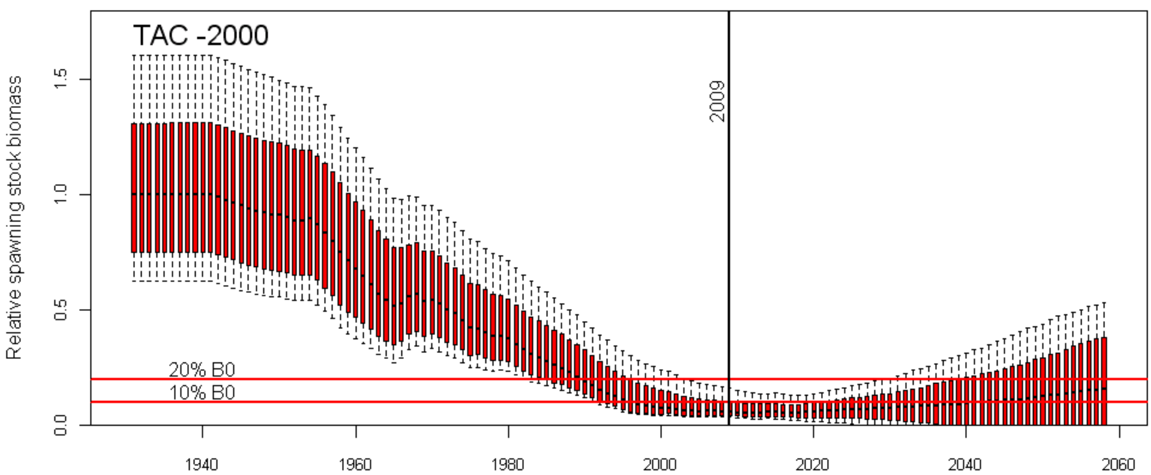
TAC +2000	10%	30%	50%
B2014/B2004	0.49	0.63	0.70
B2014/2008	0.56	0.70	0.77
B2022/B2004	0.00	0.13	0.37
B2022/B2008	0.00	0.14	0.40
B2022/B2010	0.00	0.15	0.44
B2025/B2010	0.00	0.00	0.31
B2008/B0	0.05	0.05	0.07
B2008/B1980	0.11	0.14	0.18
P(B2014>B2004)	0.06		
P(B2014>B2008)	0.02		

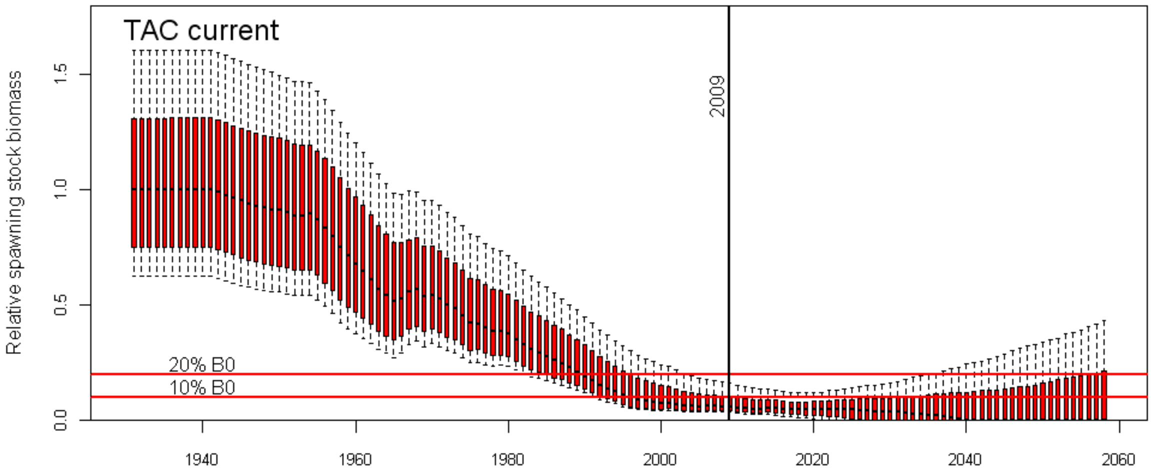
TAC -2000	10%	30%	50%
B2014/B2004	0.63	0.73	0.80
B2014/2008	0.75	0.83	0.87
B2022/B2004	0.28	0.57	0.75
B2022/B2008	0.30	0.62	0.83
B2022/B2010	0.34	0.69	0.89
B2025/B2010	0.16	0.67	0.96
B2008/B0	0.05	0.05	0.07
B2008/B1980	0.11	0.14	0.18
P(B2014>B2004)	0.17		
P(B2014>B2008)	0.13		

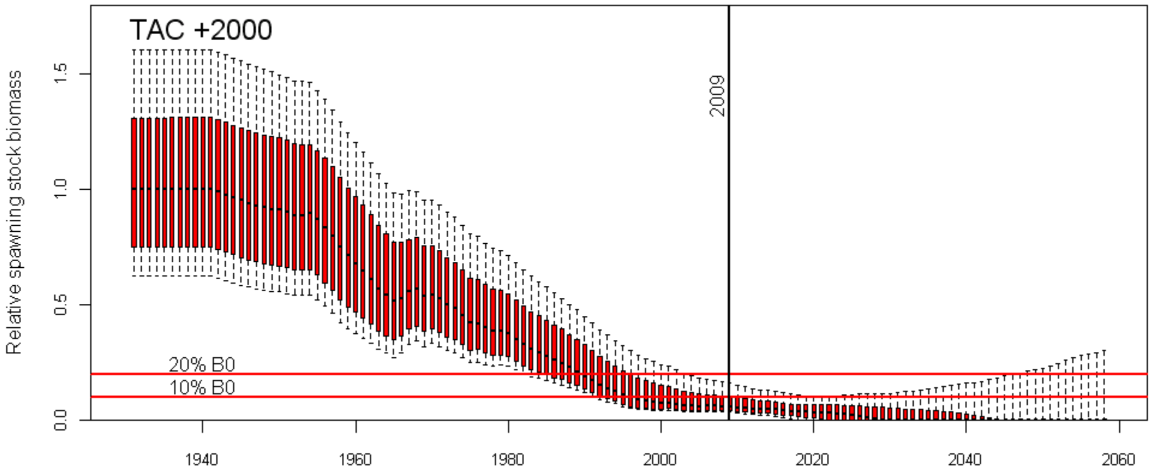
TAC +4000	10%	30%	50%
B2014/B2004	0.39	0.56	0.65
B2014/2008	0.45	0.62	0.71
B2022/B2004	0.00	0.00	0.17
B2022/B2008	0.00	0.00	0.18
B2022/B2010	0.00	0.00	0.20
B2025/B2010	0.00	0.00	0.01
B2008/B0	0.05	0.05	0.07
B2008/B1980	0.11	0.14	0.18
P(B2014>B2004)	0.04		
P(B2014>B2008)	0.01		

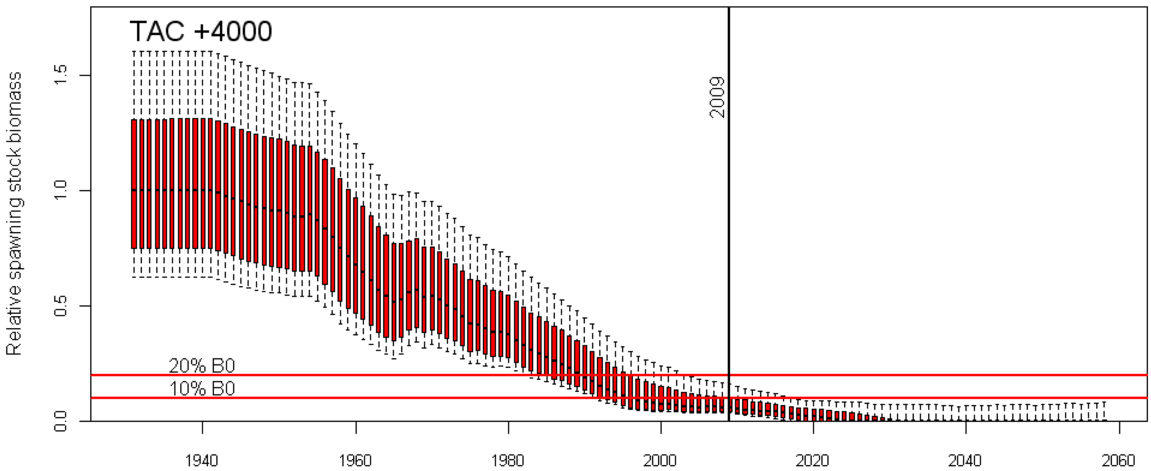

TAC zero
Relative spawning stock biomass
0.0
0.5
1.0
1.5
2009
2027
20% B0
10% B0
1940
1960
1980
2000
2020
2040
2060


TAC -4000
Relative spawning stock biomass
0.0
0.5
1.0
1.5
2009
2043
20% B0
10% B0
1940
1960
1980
2000
2020
2040
2060


TAC -2000
Relative spawning stock biomass
0.0
0.5
1.0
1.5
2009
20% B0
10% B0
1940
1960
1980
2000
2020
2040
2060


TAC current
2009
20% B0
10% B0
Relative spawning stock biomass
0.0
0.5
1.0
1.5
1940
1960
1980
2000
2020
2040
2060


TAC +2000
2009
20% B0
10% B0
Relative spawning stock biomass
0.0
0.5
1.0
1.5
1940
1960
1980
2000
2020
2040
2060


TAC +4000
2009
20% B0
10% B0
Relative spawning stock biomass
0.0
0.5
1.0
1.5
1940
1960
1980
2000
2020
2040
2060

Base case (no tag)

The OM setting the tag likelihood component to zero suggests the current median spawning biomass is at 8% of unexploited spawning biomass.

Short-term projections of constant catches at, or above, the current TAC, indicate that:

- the probability that the median spawning biomass in 2014 will be lower than 2004 or 2008, is very high (ranging from 85% and 92%, respectively, for the case where the current TAC is used, to 94% and 99% when the catch is 4000 t above TAC);
- for a constant catch at current TAC levels, there is a 50% chance that the median spawning biomass in 2014 will be greater than 79% of 2004 levels, and greater than 85% of 2008 levels.

Short-term projections of constant catches of 2000 t or more, less than the current TAC indicate that:

- the probability that the median spawning biomass in 2014 will be lower than 2004 or 2008, is still high for the cases where catch is 4000 t and 2000 t less than the current TAC (70% and 65%, respectively, in the minus 4000 t catch case, and 76% and 84% in the minus 2000 t case).
- for a constant catch of zero, there is a 50% chance that the median spawning biomass in 2014 will be greater than 2004 levels, and a 70% chance that it is greater than 2008 levels.

TAC zero	10%	30%	50%
B2014/B2004	0.84	0.95	1.09
B2014/2008	0.97	1.05	1.16
B2022/B2004	1.19	1.53	1.95
B2022/B2008	1.34	1.69	2.06
B2022/B2010	1.42	1.77	2.11
B2025/B2010	1.65	2.13	2.66
B2008/B0	0.05	0.06	0.08
B2008/B1980	0.12	0.16	0.19
P(B2014>B2004)	0.62		
P(B2014>B2008)	0.84		

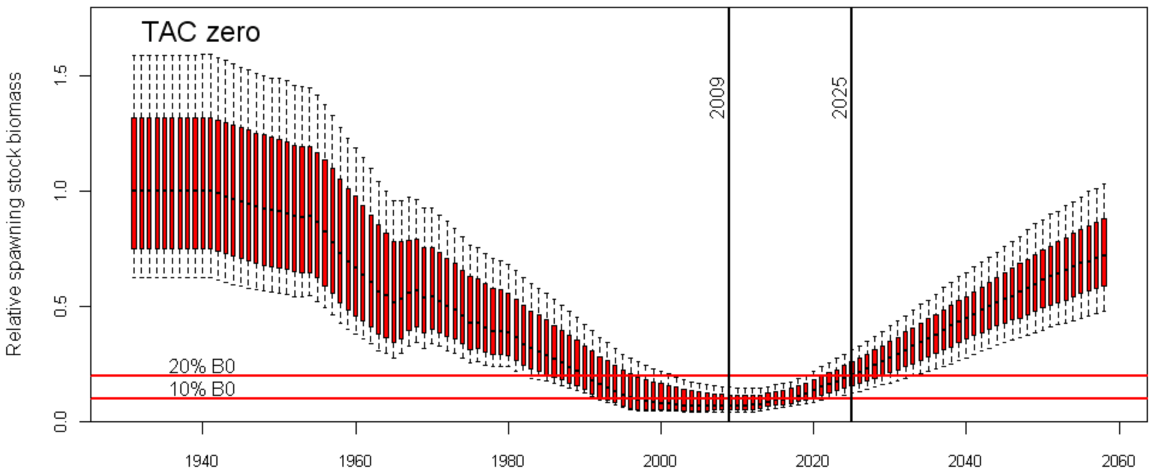
TAC Current	10%	30%	50%
B2014/B2004	0.61	0.72	0.79
B2014/2008	0.73	0.80	0.85
B2022/B2004	0.19	0.48	0.64
B2022/B2008	0.22	0.52	0.70
B2022/B2010	0.25	0.57	0.75
B2025/B2010	0.00	0.49	0.75
B2008/B0	0.05	0.06	0.08
B2008/B1980	0.12	0.16	0.19
P(B2014>B2004)	0.15		
P(B2014>B2008)	0.08		

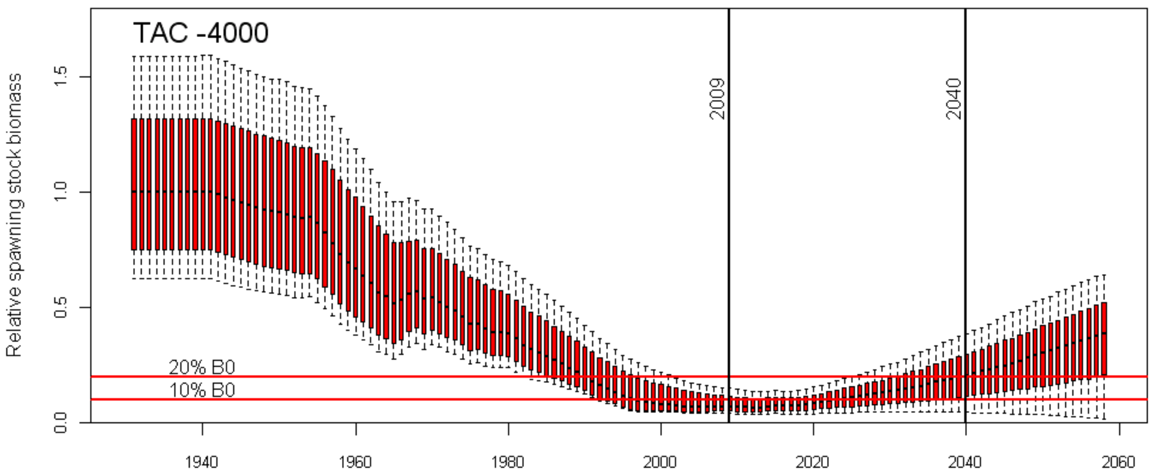
TAC -4000	10%	30%	50%
B2014/B2004	0.71	0.80	0.89
B2014/2008	0.84	0.90	0.95
B2022/B2004	0.61	0.83	1.05
B2022/B2008	0.69	0.91	1.11
B2022/B2010	0.75	0.98	1.19
B2025/B2010	0.75	1.07	1.39
B2008/B0	0.05	0.06	0.08
B2008/B1980	0.12	0.16	0.19
P(B2014>B2004)	0.30		
P(B2014>B2008)	0.35		

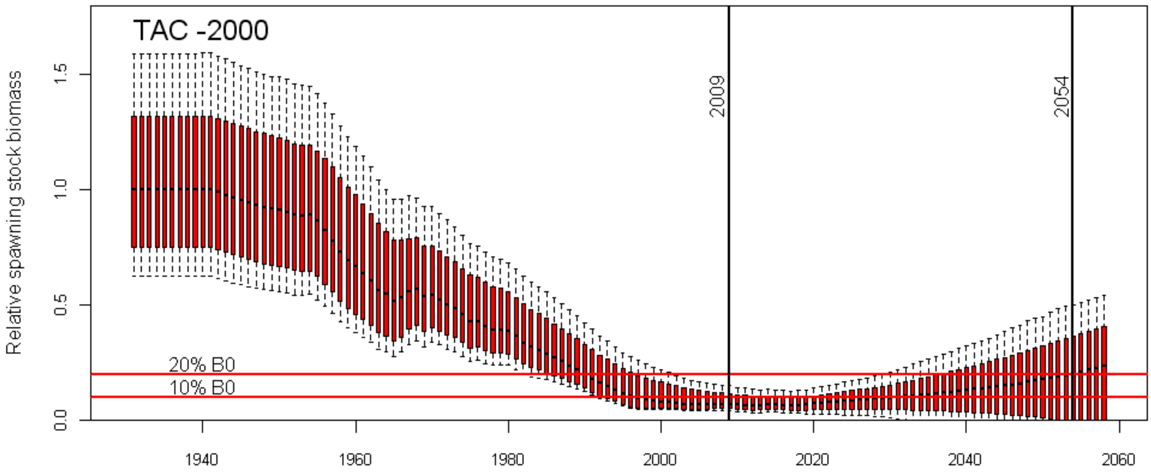
TAC +2000	10%	30%	50%
B2014/B2004	0.57	0.68	0.74
B2014/2008	0.65	0.75	0.80
B2022/B2004	0.00	0.29	0.47
B2022/B2008	0.00	0.32	0.50
B2022/B2010	0.00	0.35	0.54
B2025/B2010	0.00	0.17	0.47
B2008/B0	0.05	0.06	0.08
B2008/B1980	0.12	0.16	0.19
P(B2014>B2004)	0.10		
P(B2014>B2008)	0.04		

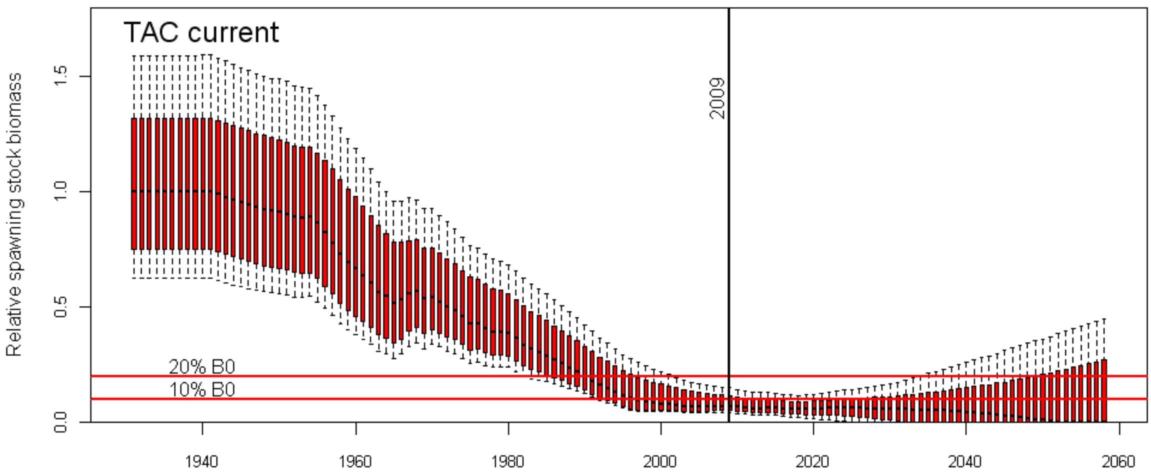
TAC -2000	10%	30%	50%
B2014/B2004	0.67	0.77	0.85
B2014/2008	0.79	0.85	0.90
B2022/B2004	0.43	0.66	0.85
B2022/B2008	0.47	0.71	0.90
B2022/B2010	0.53	0.77	0.97
B2025/B2010	0.43	0.78	1.06
B2008/B0	0.05	0.06	0.08
B2008/B1980	0.12	0.16	0.19
P(B2014>B2004)	0.24		
P(B2014>B2008)	0.16		

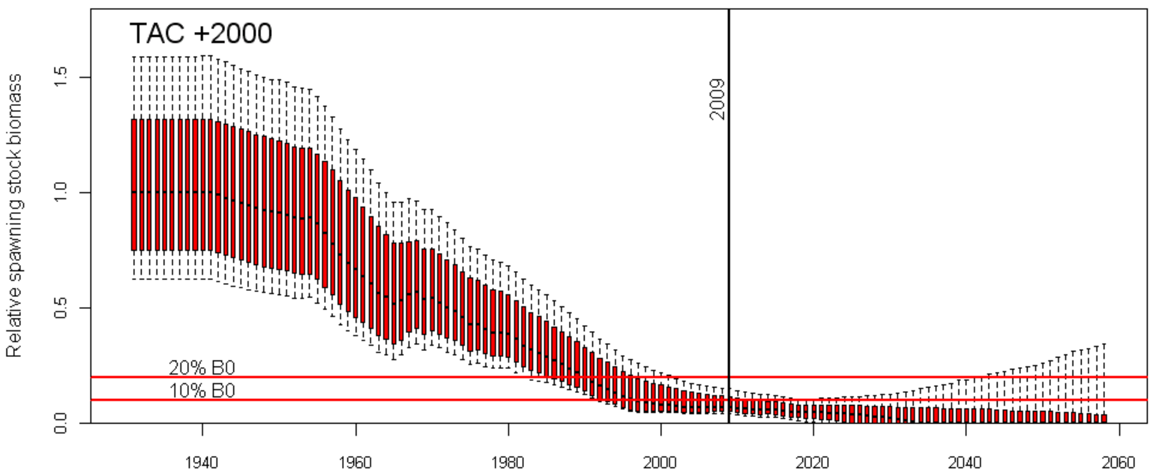
TAC +4000	10%	30%	50%
B2014/B2004	0.49	0.63	0.69
B2014/2008	0.55	0.69	0.75
B2022/B2004	0.00	0.07	0.30
B2022/B2008	0.00	0.07	0.32
B2022/B2010	0.00	0.08	0.36
B2025/B2010	0.00	0.00	0.17
B2008/B0	0.05	0.06	0.08
B2008/B1980	0.12	0.16	0.19
P(B2014>B2004)	0.06		
P(B2014>B2008)	0.01		

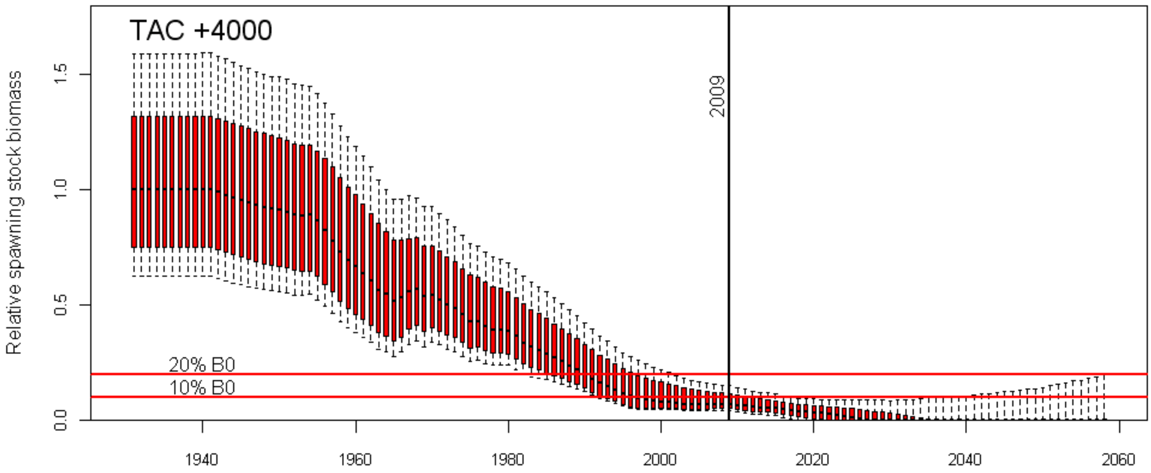





TAC -2000
Relative spawning stock biomass
0.0
0.5
1.0
1.5
2009
2054
20% B0
10% B0
1940
1960
1980
2000
2020
2040
2060


TAC current
Relative spawning stock biomass
0.0
0.5
1.0
1.5
2009
20% B0
10% B0
1940
1960
1980
2000
2020
2040
2060


TAC +2000
Relative spawning stock biomass
0.0
0.5
1.0
1.5
2009
20% B0
10% B0
1940
1960
1980
2000
2020
2040
2060


TAC +4000
Relative spawning stock biomass
2009
20% B0
10% B0
0.0
0.5
1.0
1.5
1940
1960
1980
2000
2020
2040
2060

Projections with current TAC for all scenarios

The following tables give the reference points for the different scenarios investigated as part of robustness testing, where constant catch projections have been made using the current TAC. This table can be used in analysing the sensitivity of the OM to the different model assumptions through comparison of values and assessing whether management action would differ under different model assumptions. Using the old tag likelihood or setting the tag NLL component to zero tend to give more optimistic values in terms of the reference points. Differences between the other trials were minimal.

Scenario	B2014/B2004			B2014/B2008			B2022/B2004			B2022/B2008			B2022/B2010			B2025/B2010		
	10%	30%	50%	10%	30%	50%	10%	30%	50%	10%	30%	50%	10%	30%	50%	10%	30%	50%
Base	0.00	0.40	0.59	0.00	0.48	0.69	0.00	0.00	0.12	0.00	0.00	0.14	0.00	0.00	0.16	0.00	0.00	0.00
CPUE S=0%	0.00	0.39	0.60	0.00	0.47	0.69	0.00	0.00	0.19	0.00	0.00	0.23	0.00	0.00	0.26	0.00	0.00	0.04
CPUE S=50%	0.00	0.34	0.57	0.00	0.42	0.66	0.00	0.00	0.05	0.00	0.00	0.06	0.00	0.00	0.07	0.00	0.00	0.00
CPUE S=75%	0.00	0.24	0.55	0.00	0.31	0.64	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.00
CV 0.3+tau=0	0.00	0.22	0.49	0.00	0.30	0.61	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00
LLH weights	0.00	0.22	0.49	0.00	0.30	0.61	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00
Tag NLL=0	0.61	0.72	0.79	0.73	0.80	0.85	0.19	0.48	0.64	0.22	0.52	0.70	0.25	0.57	0.75	0.00	0.49	0.75
Old Tag LLH	0.57	0.68	0.75	0.67	0.77	0.82	0.00	0.36	0.56	0.00	0.40	0.61	0.00	0.44	0.67	0.00	0.31	0.62

Scenario	B2008/B0			B2008/B1980			MSY			P(B2014>B2004)	P(B2014>B2008)
	10%	30%	50%	10%	30%	50%	10%	30%	50%		
Base	0.02	0.03	0.05	0.05	0.09	0.14	16715	21749	24632	0.02	0.01
CPUE S=0%	0.02	0.04	0.05	0.05	0.09	0.13	16556	21733	24882	0.03	0.02
CPUE S=50%	0.02	0.03	0.05	0.04	0.09	0.14	16608	21487	24736	0.02	0.01
CPUE S=75%	0.01	0.03	0.05	0.03	0.09	0.14	16689	21299	24483	0.02	0.00
CV 0.3+tau=0	0.02	0.03	0.04	0.04	0.08	0.13	16525	21566	24684	0.01	0.01
LLH weights	0.02	0.03	0.04	0.04	0.08	0.13	16525	21566	24684	0.01	0.01
Tag NLL=0	0.05	0.06	0.08	0.12	0.16	0.19	16817	21780	24560	0.15	0.08
Old Tag LLH	0.05	0.05	0.07	0.11	0.14	0.18	16715	21749	24632	0.11	0.06

Robustness trials investigated with previous version of code

As was mentioned earlier, other robustness trials were investigated with the previous version of the code (before the correction to the aerial survey likelihood component). Some of the main observations are included here for reference.

In the boxplots of the main NLL components of the model, it was noted that there was a much smaller range for the LL1-4 components relating to the trial including the troll survey, compared to the other trials. This has not been further investigated.

Using GridView, the ‘base case’ grid cell with the CPUE series truncated in 1992 was considered: there were no discernable differences in the S-R relationship, the S-R residuals, the spawning biomass, recruitment or model fits to the data, when compared with the case including the full series. In the case of breaking the CPUE into two time series in 1986, again the results showed no change from the ‘base case’ grid cell results. The case of increasing the CV of CPUE (without setting τ_{aerial} to 0) also produced negligible changes in the GridView plots and data fits compared with the ‘base case’ grid cell. When the troll survey was included, there were some minor changes: the S-R relationship increased slightly, and the residuals were slightly adjusted, but there were no significant changes in the data fits or other GridView plots.

In the constant catch projections, the trial with the CPUE series truncated in 1992 produced more pessimistic results than the rest of the trials. All other trials produced similar results to the base case suggesting robustness under these scenarios.

Summary

The results presented in this paper should be regarded as preliminary findings and it should be recognised that comprehensive evaluation of model fits and analysis of the full set of robustness trials has not been carried out. In respect to the long-term projections, it should be emphasised that such projections should be considered with caution due to assumptions about future catches and recruitments in the absence of a feedback MP.

Refinements to OM and reference set

Key observations and considerations in terms of the new OM and future refinements:

- Model convergence issues have been identified, for the ORIG.5 data weighting option in particular. These were not evident when the old tagging model was used. Setting parameter estimation to occur in a later phase could solve this issue, but this has not been explored.
- The median of the CPUE NLL components increased as the CPUE scaling increased beyond S = 0.25. There was little difference between the cases of S = 0 and S = 0.25. Further, an increase in S led to poorer convergence gradients.
- The impact of setting the CPUE CV to 0.3 (default 0.2) and τ_{aerial}=0, had negligible impact on the NLL components, although it did improve convergence gradients considerably in the case of the ORIG.5 data weighting option.
- For the grid cells considered, model fits to the length and age data were good, with the exception of LL3 length data.
- Using likelihood-based projection weights for M0, M10 and Omega for the grid integration led to the upper value of M0 not being sampled, and a favouring of the lowest value. For M10, higher values were sampled more often, with the lowest value rarely used. As this has been a fairly consistent feature of the OM over the years, consideration should be given in the meeting to what the weighting of M0 and M10 in the grid should be.
- Grid values for Omega, when using likelihood-based projection weights for M0, M10 and Omega for the grid integration, were more equally favoured when using the new tag likelihood whereas using the old tag likelihood gave a preference for the higher value.

Preliminary results on stock status and constant catch projections

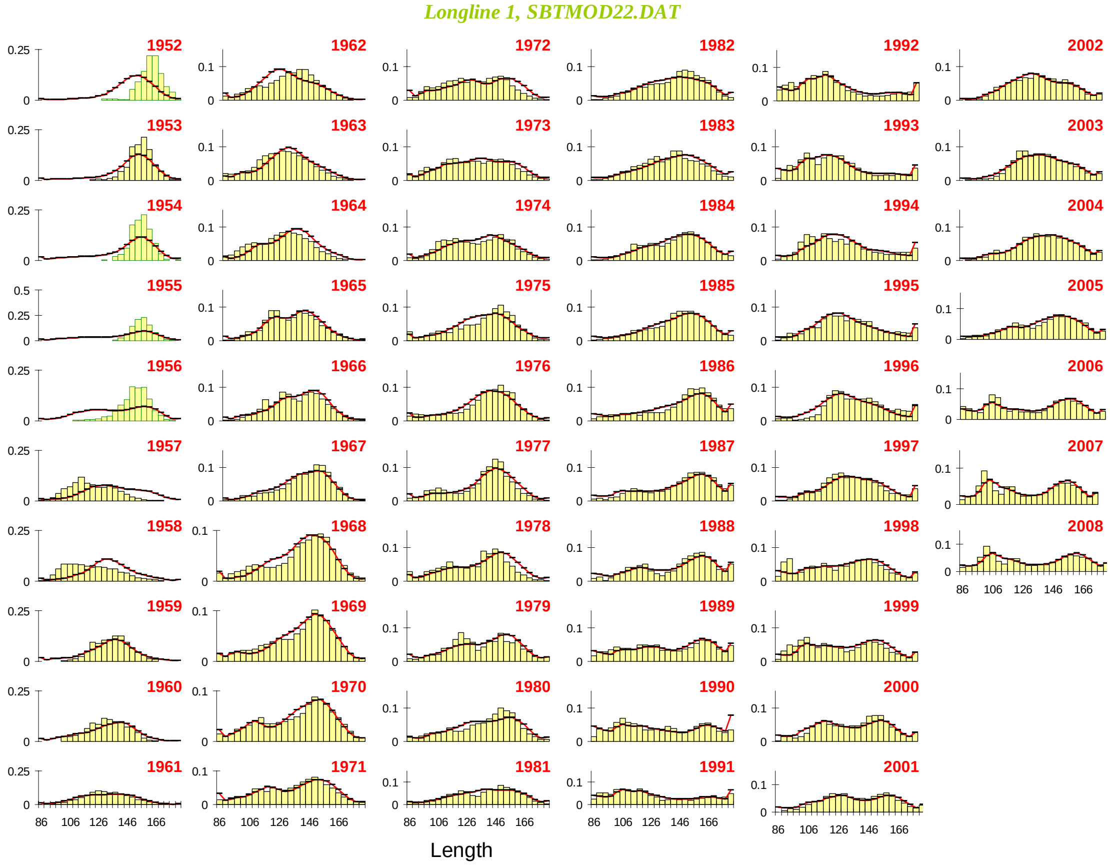
Key observations and results in terms of stock status and constant catch projections are:

- Over all trials investigated, the median values suggest the current spawning biomass is in the range of 4-8% of unfished spawning biomass.
- Using the old tag likelihood or setting the tag NLL component to zero tended to give slightly more optimistic determinations of current and projected spawning biomass. Differences between the other trials in terms of reference points were minimal.
- Based on the zero constant catch projections for the base case, B20 levels are 50% likely by 2030. Applying the old tagging model does not change this outcome significantly (50% likely in 2027); nor does excluding the tagging from the likelihood function (50% likely in 2025).

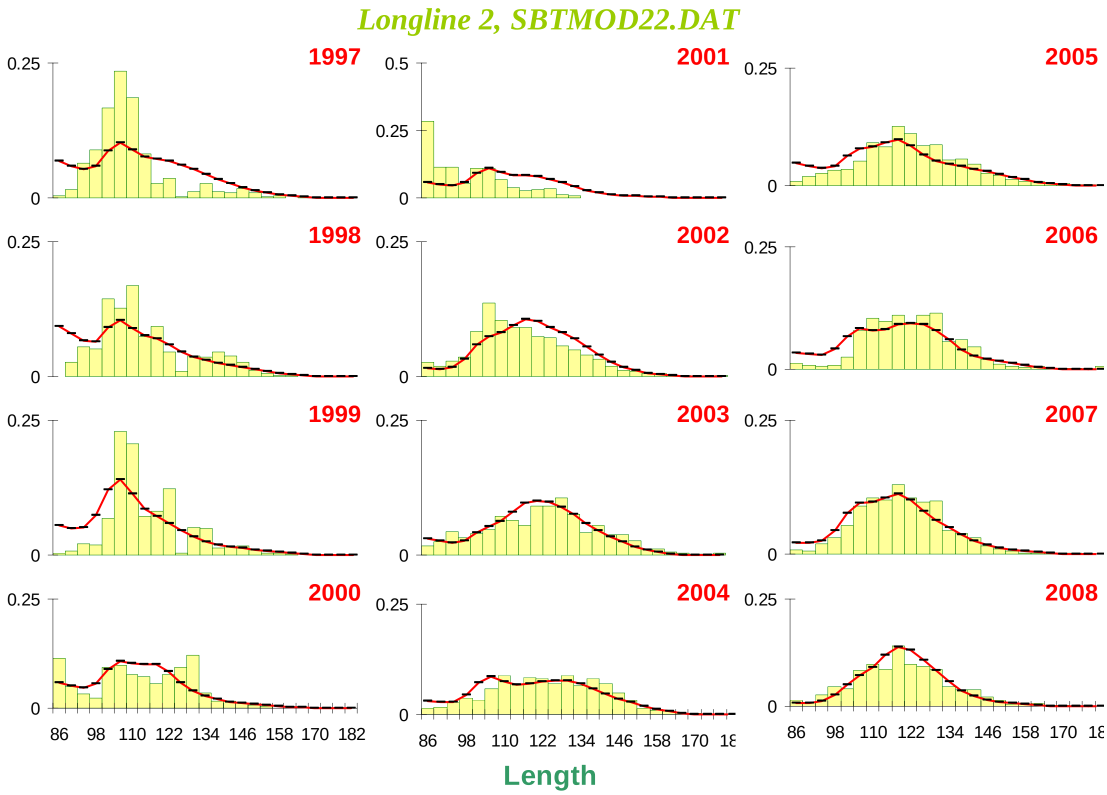
Appendix A

Length and age data fits for the 'base case' grid cell (c1s1l1ORIG.5_h1m1M1O1C2a1). As noted above, there were only minor changes in these fits for the grid cells considered.

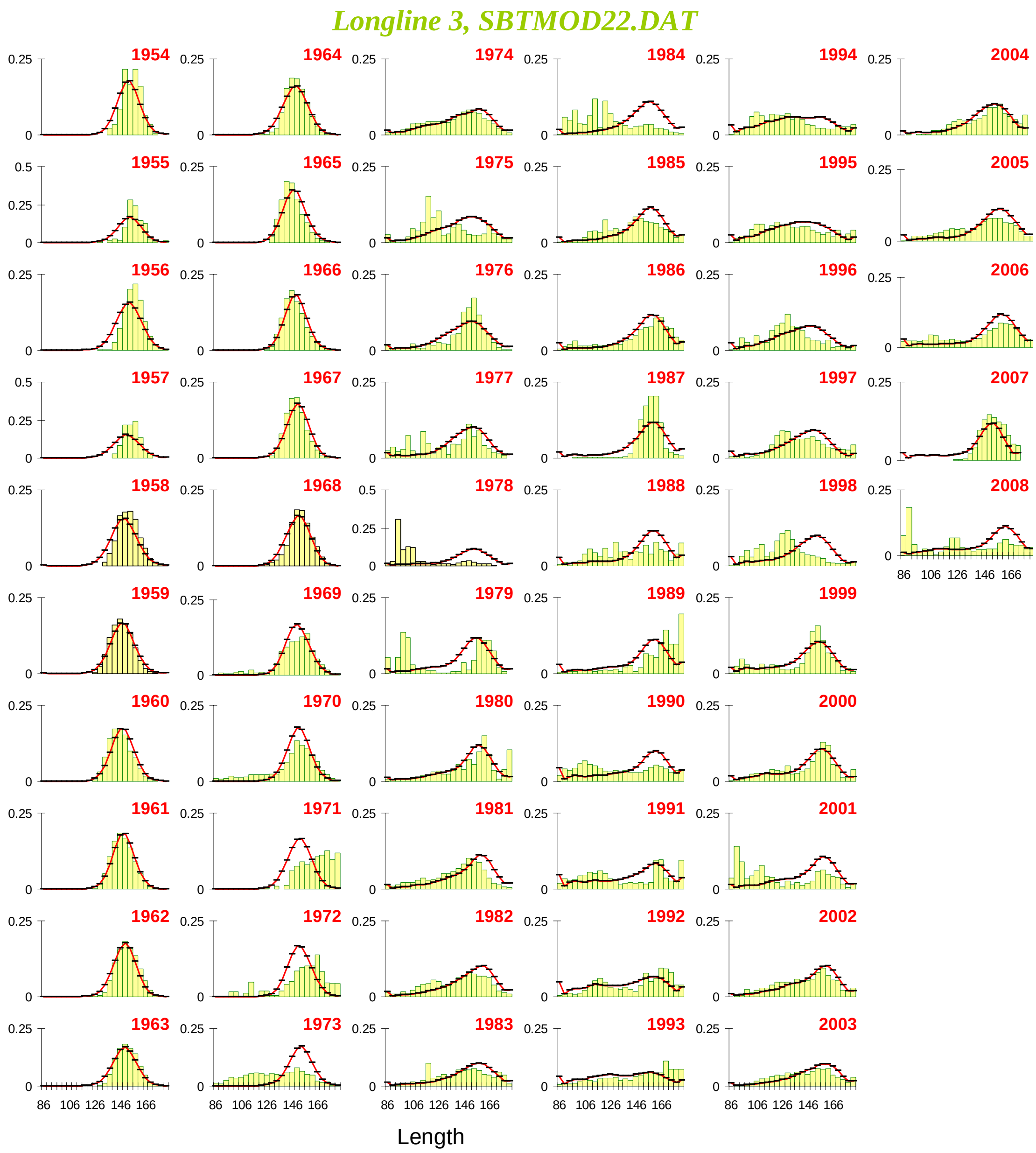
LL1:



LL2:


Longline 2, SBTMOD22.DAT
1997
2001
2005
1998
2002
2006
1999
2003
2007
2000
2004
2008
0.25
0.5
0
86
98
110
122
134
146
158
170
182
Length

LL3:


Longline 3, SBTMOD22.DAT
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
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1969
1970
1971
1972
1973
1974
1975
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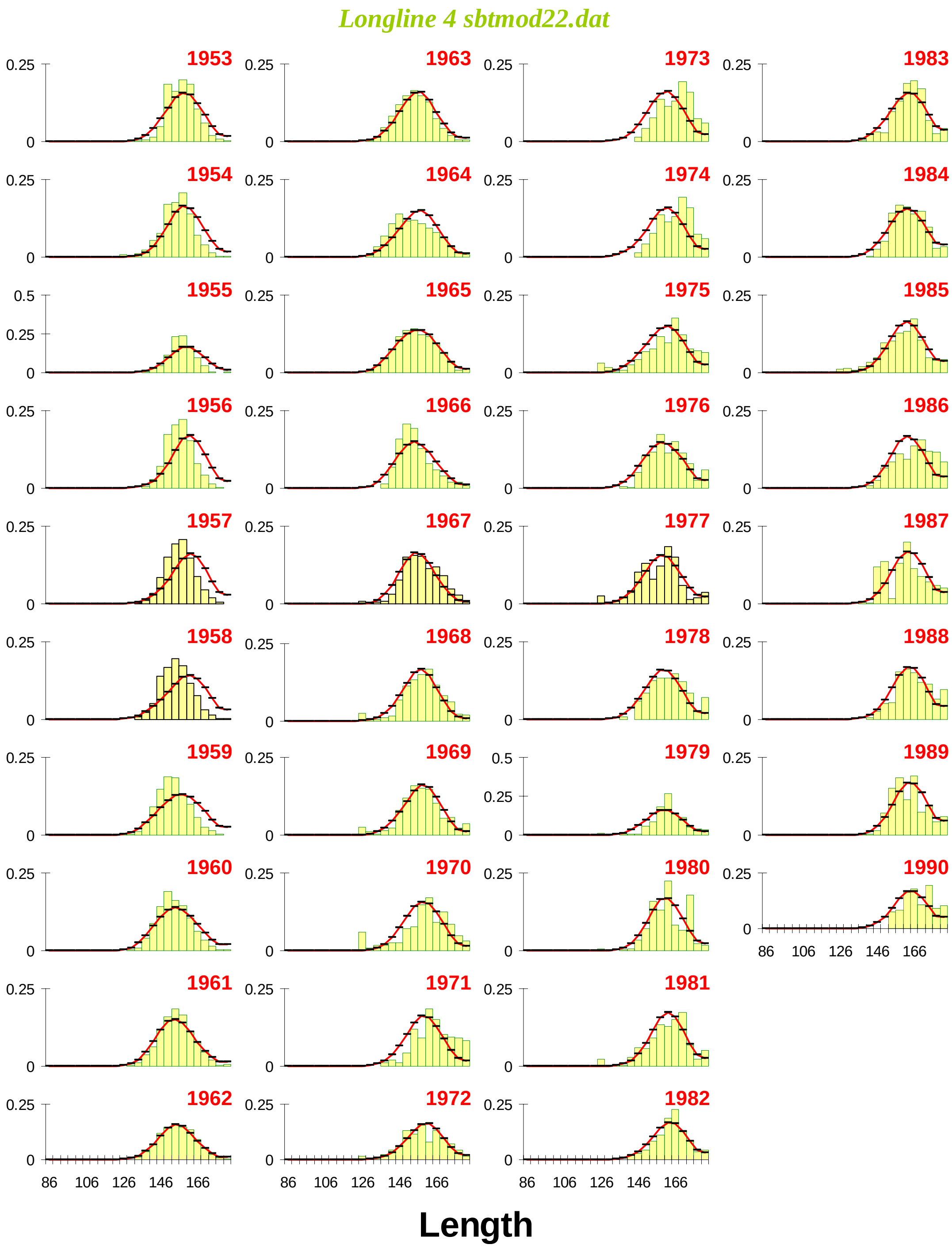
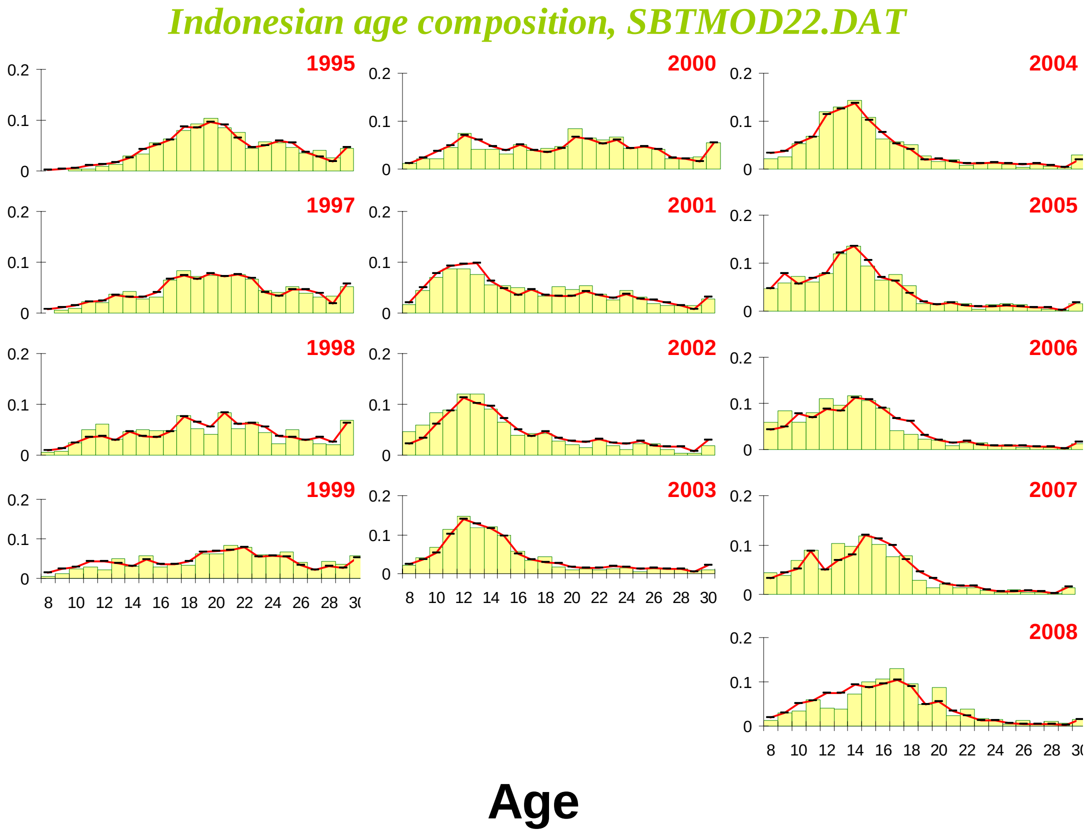
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
0.25
0.5
0
86 106 126 146 166
Length

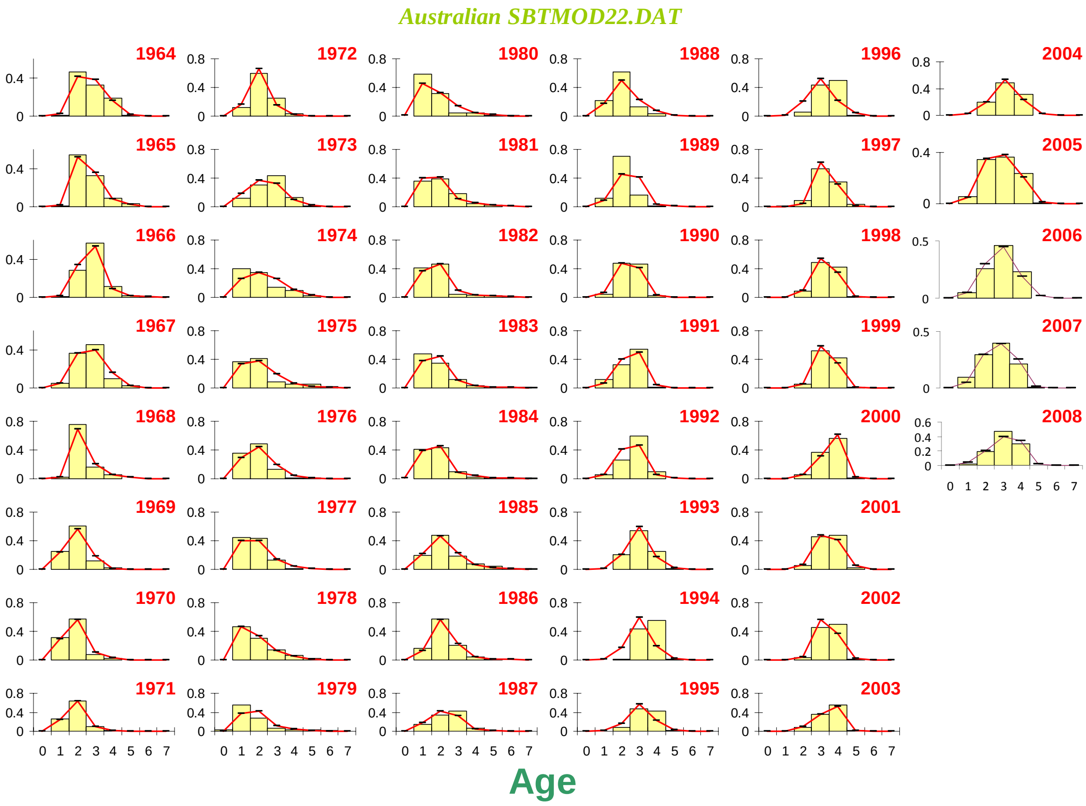
LL4:


Longline 4 sbtmod22.dat
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
0.5
0.25
0
86
106
126
146
166
Length

Indonesian Age Data:



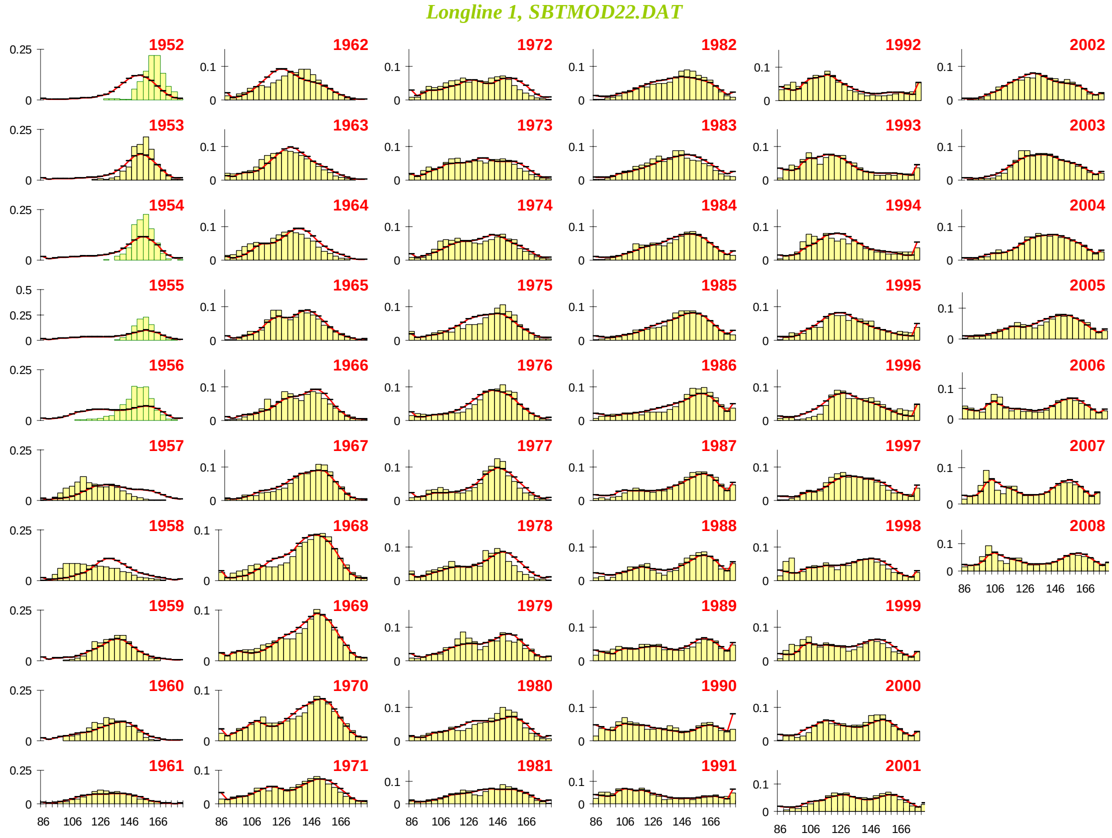
Australian Surface Age Data:



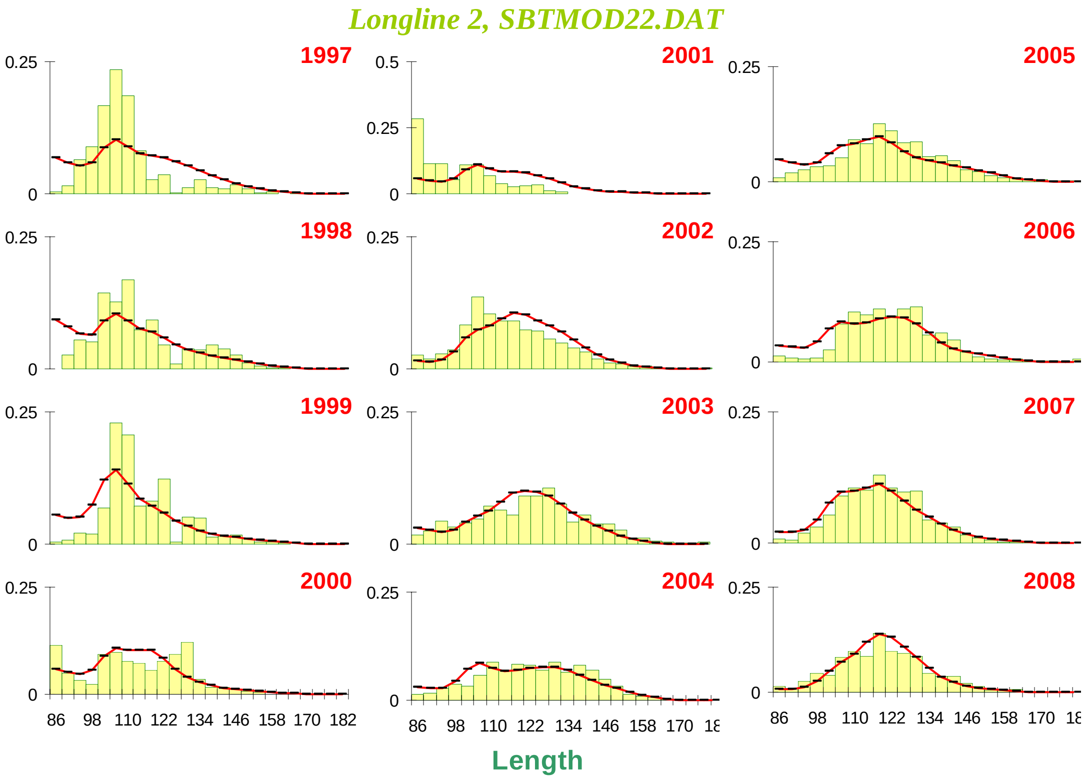
Appendix B

Length and age fits for CPUE scaling of 50% (**c2**s1l1ORIG.5_h1m1M1O1C2a1)

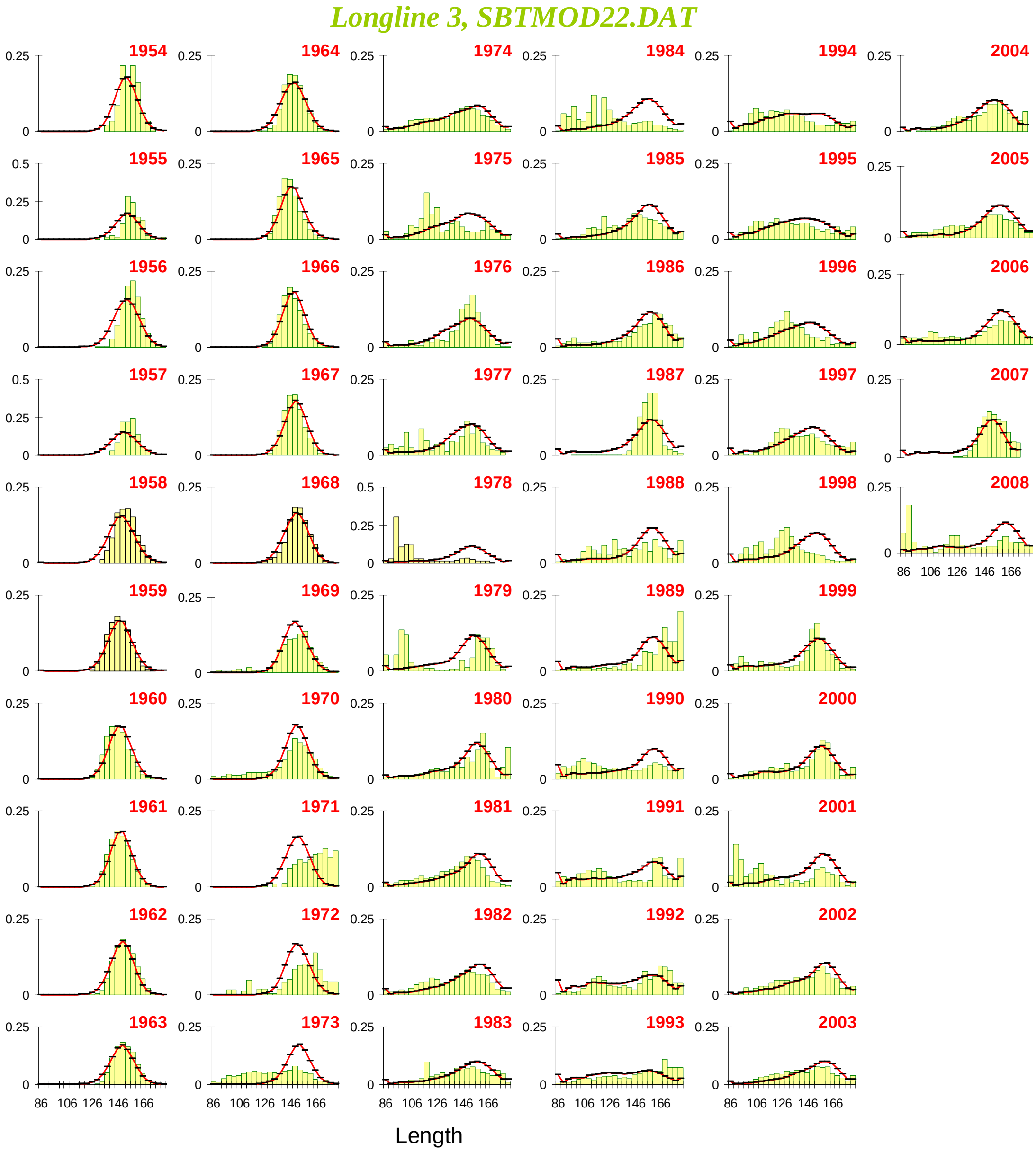
LL1 (S=0.5 - **c2**s1l1ORIG.5_h1m1M1O1C2a1):



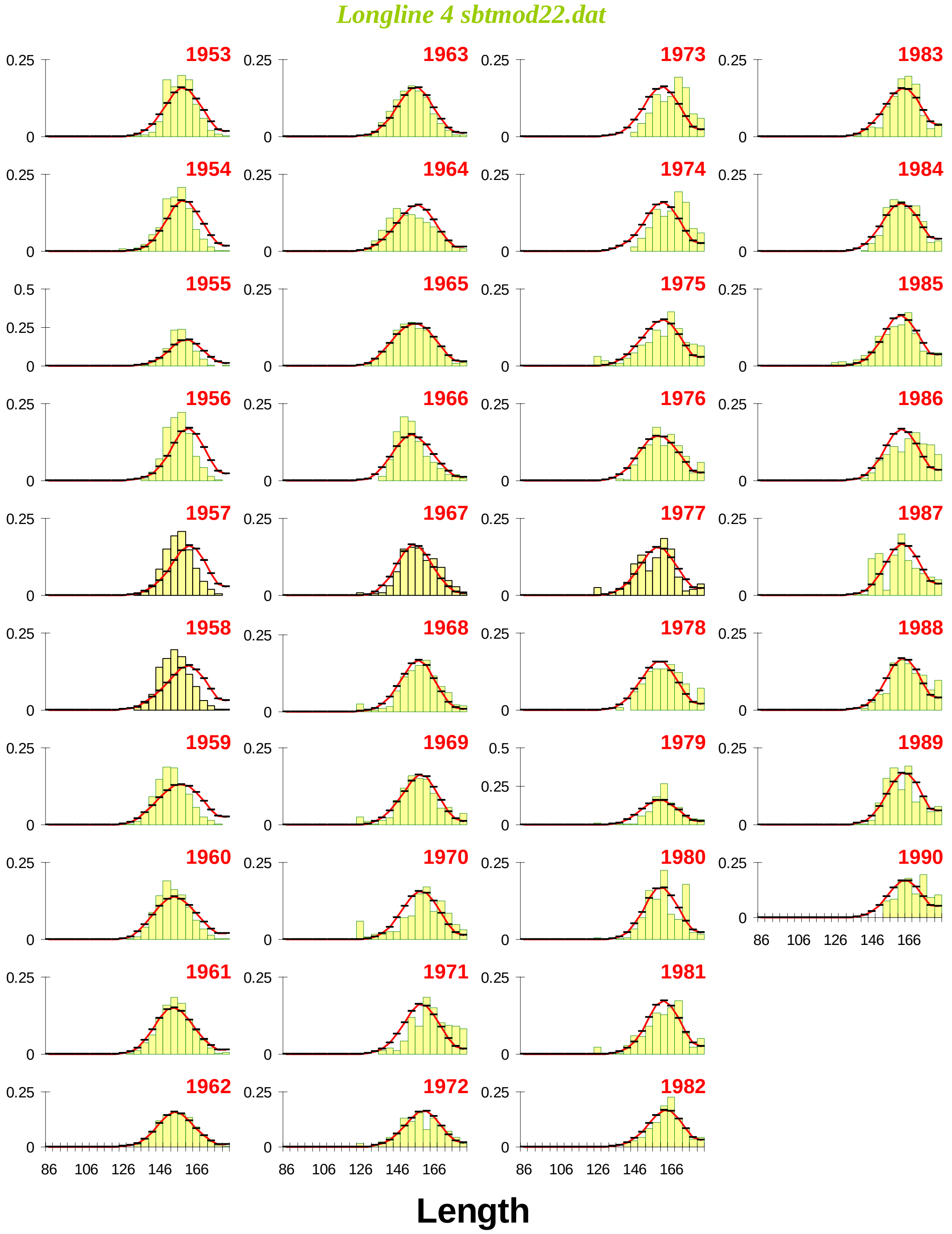
LL2 (S=0.5 - **c2**s1l1ORIG.5_h1m1M1O1C2a1):



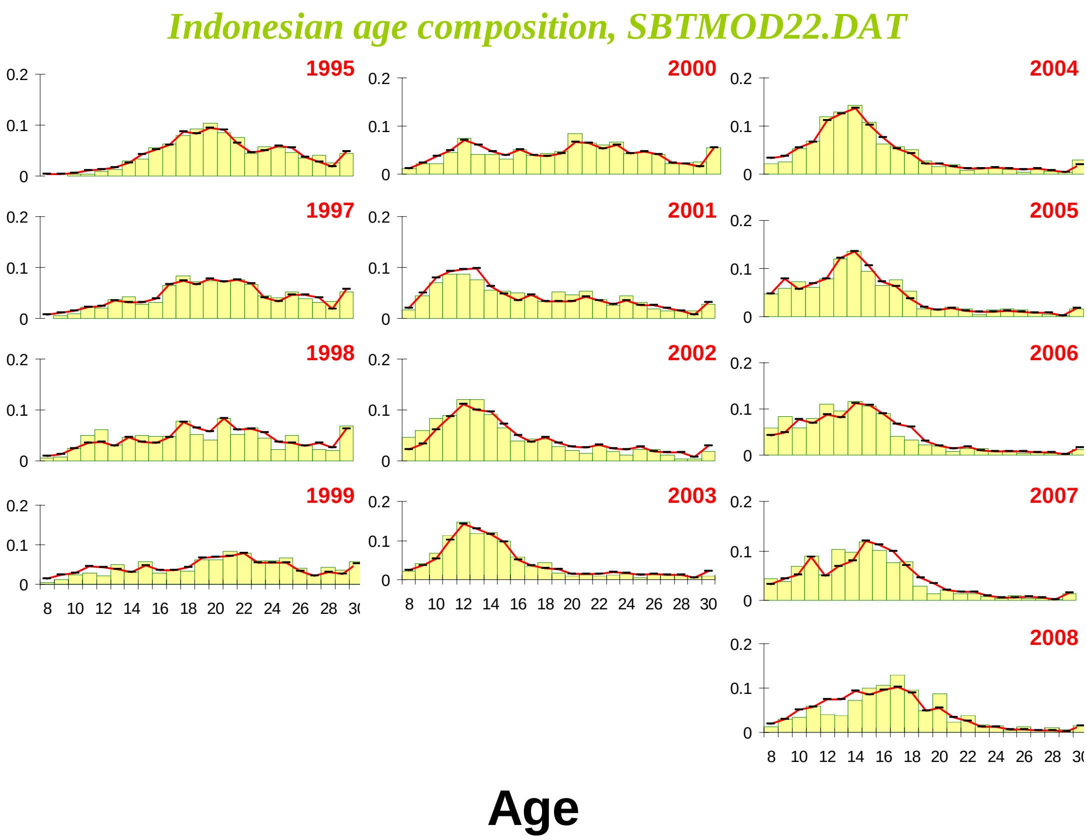
LL3 (S=0.5 - **c2**s1l1ORIG.5_h1m1M1O1C2a1):



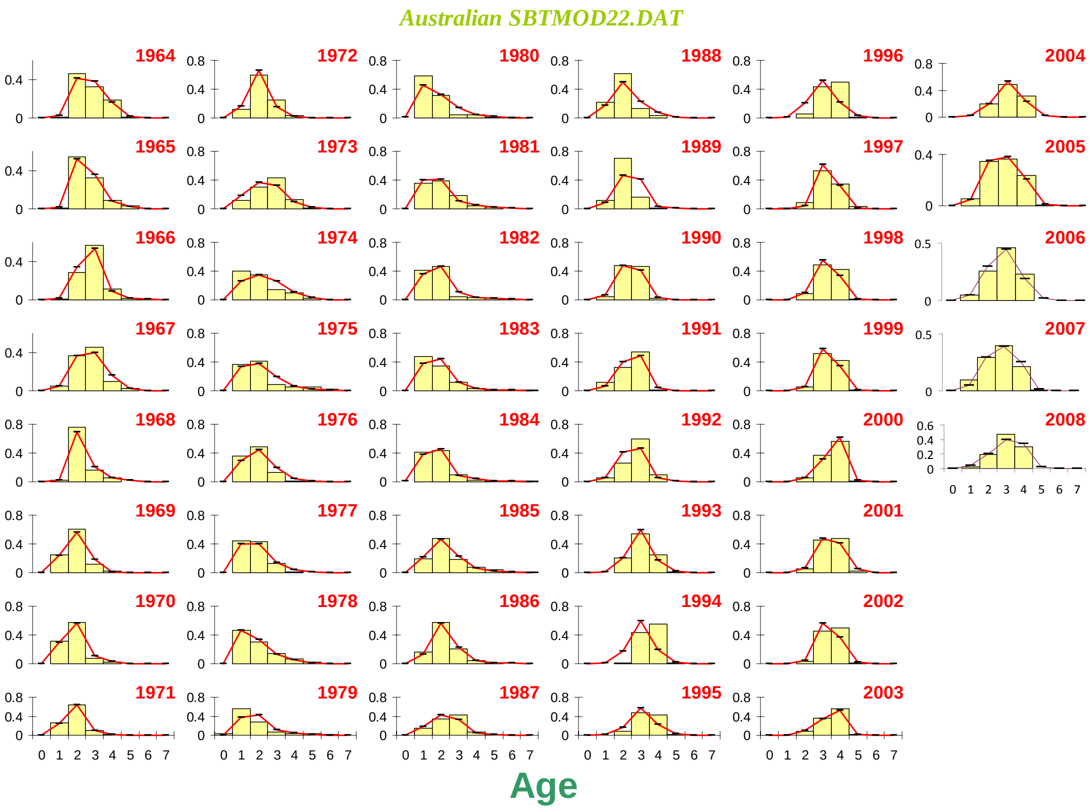
LL4 (S=0.5 - **c2**s1l1ORIG.5_h1m1M1O1C2a1):



Indonesian age data (S=0.5 - **c2**s1l1ORIG.5_h1m1M1O1C2a1):



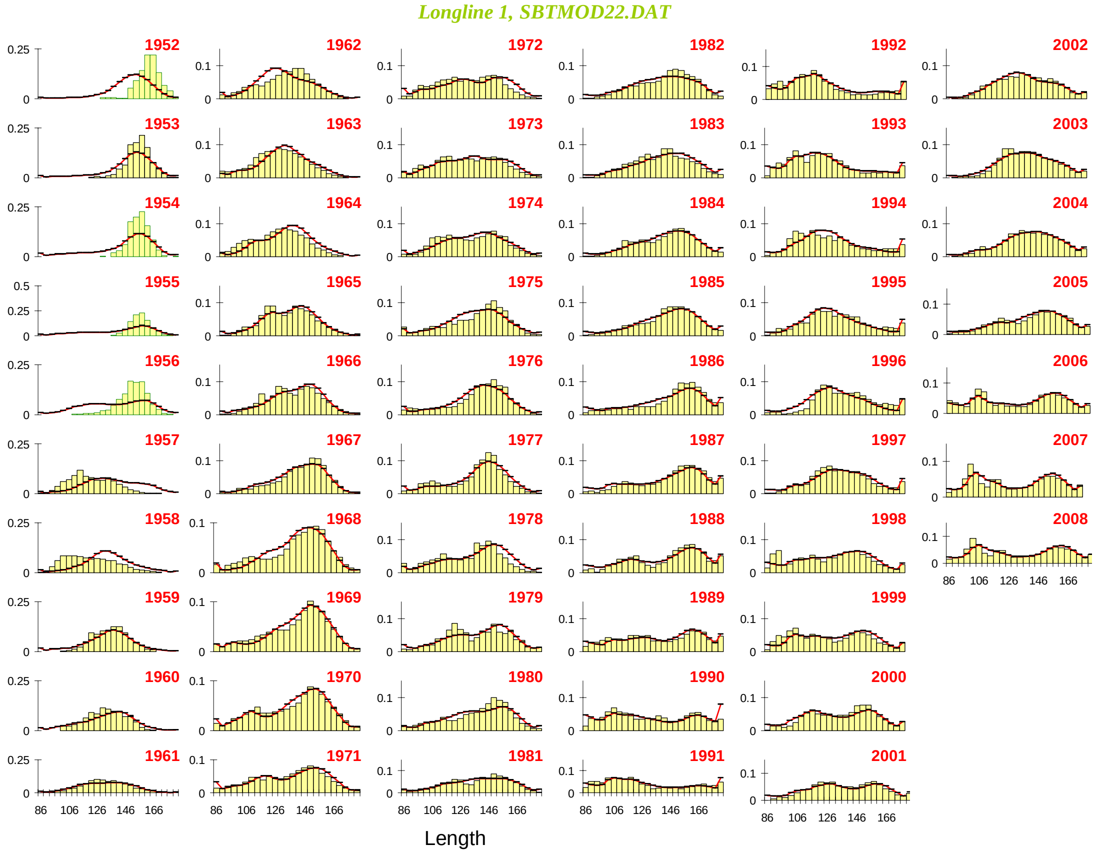
Australian surface age data (S=0.5 - **c2**s1l1ORIG.5_h1m1M1O1C2a1):



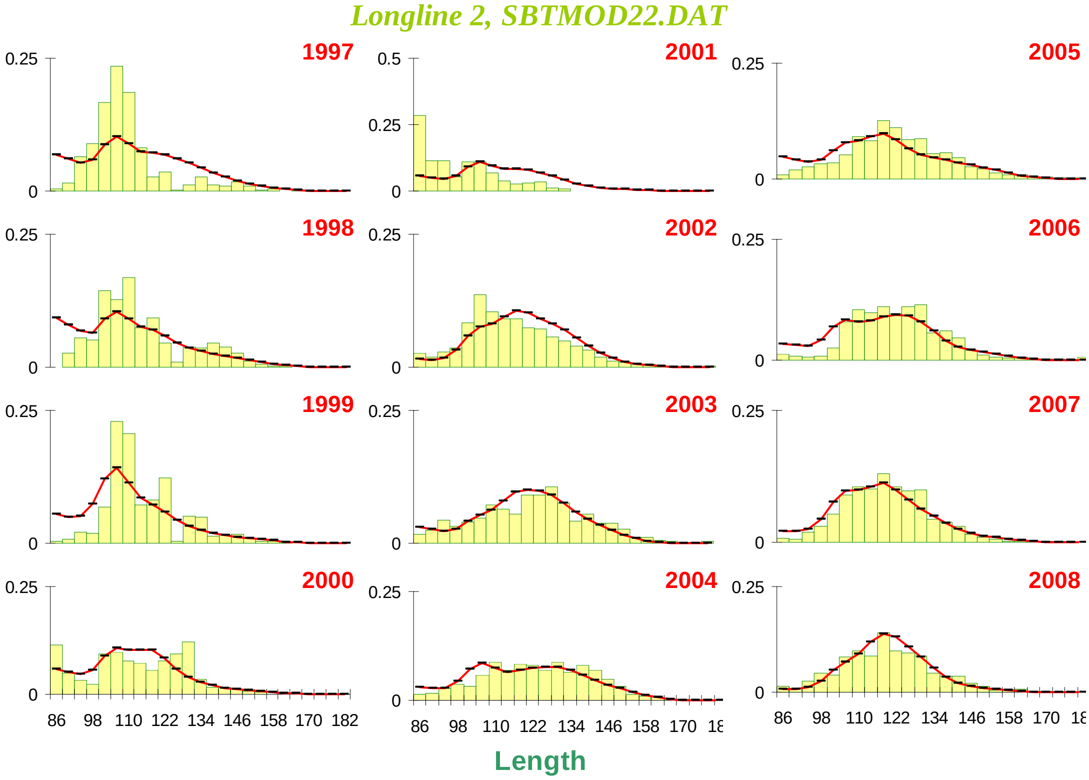
Appendix C

Length and age fits for CPUE scaling of 75% (**c3**s1l1ORIG.5_h1m1M1O1C2a1)

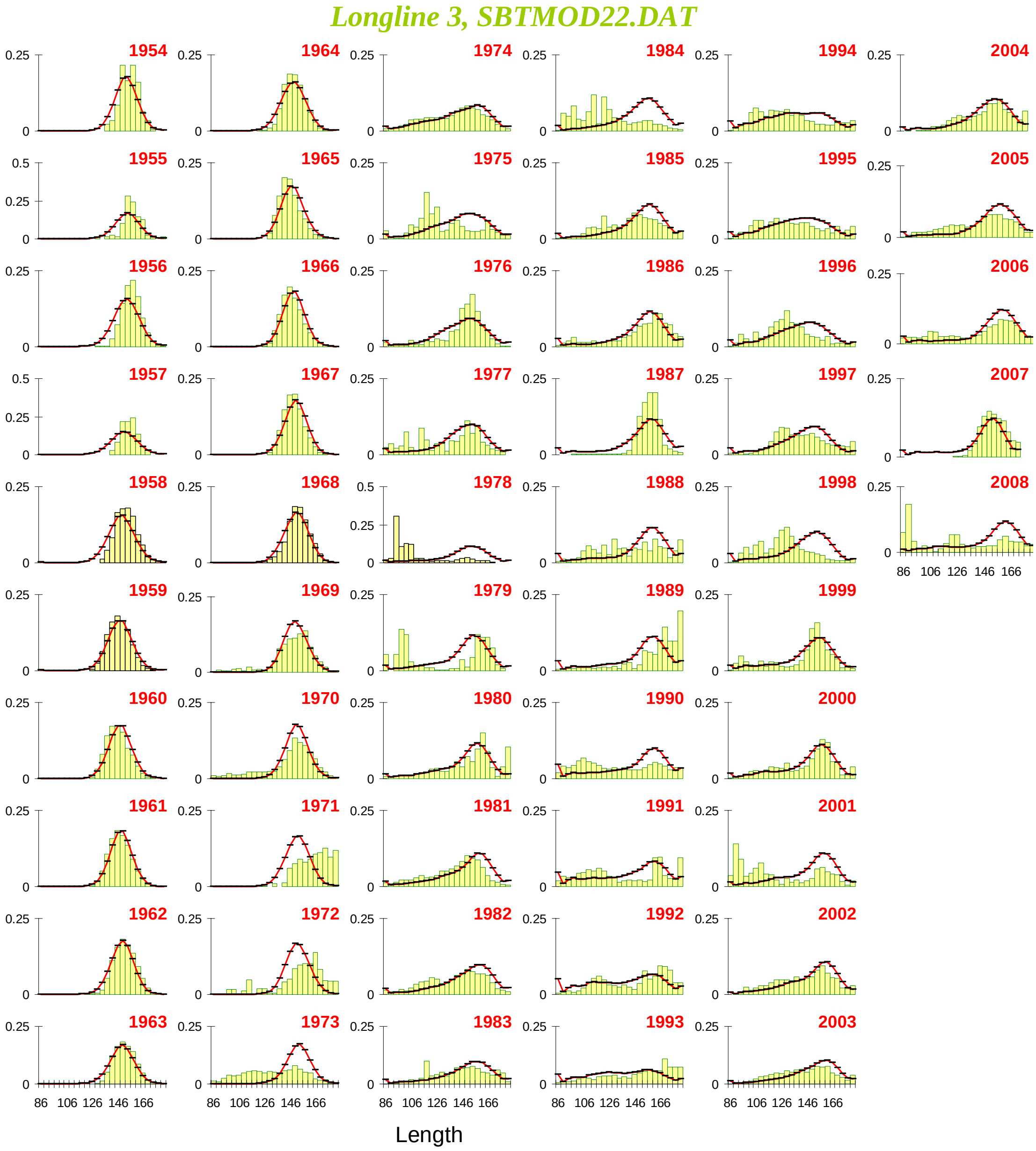
LL1 (S=0.75 -
c3s1l1ORIG.5_h1m1M1O1C2a1):



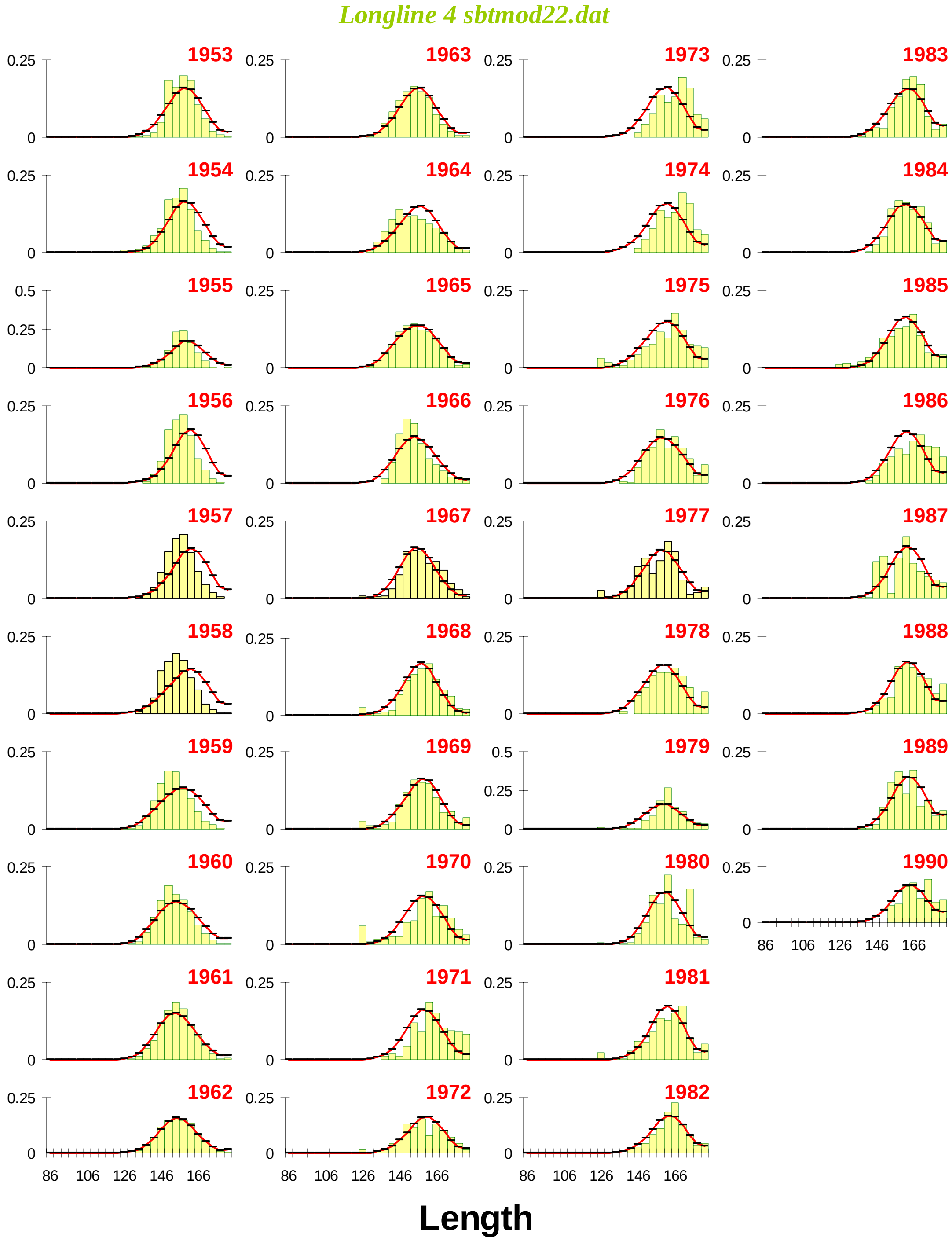
LL2 (S=0.75 - **c3**s1l1ORIG.5_h1m1M1O1C2a1):



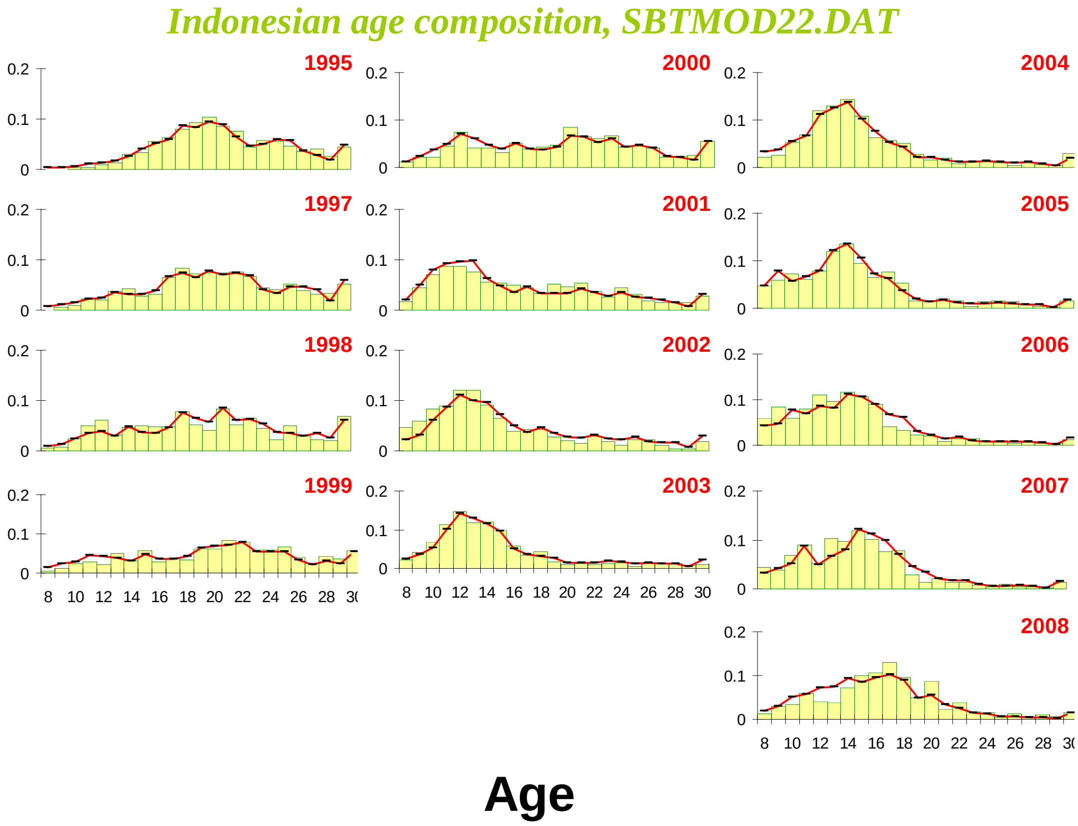
LL3 (S=0.75 - **c3**s1l1ORIG.5_h1m1M1O1C2a1):



LL4 (S=0.75 - **c3**s1l1ORIG.5_h1m1M1O1C2a1):



Indonesian age data (S=0.75 - **c3**s1l1ORIG.5_h1m1M1O1C2a1):



Australian surface age data (S=0.75 - **c3**s1l1ORIG.5_h1m1M1O1C2a1):