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Conditioning of the southern bluefin tuna operating model and constant catch projections

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Abstract

In 2009 the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) will consider advice from the Extended Scientific Committee (ESC) on the current status of the southern bluefin tuna (SBT) stock and the potential implications of different future catch levels. This advice will be based on constant catch projections using a “re-conditioned” CCSBT Operating Model (OM) and an analysis of fisheries indicators (Anon 2008). A CCBST Operating Model and Management Procedure Technical Meeting (OMMP) was held in Seattle (13-17 July 2009) to “re-condition” the OM (Anon 2009). Outcomes of the OMMP meeting included a revised mortality schedule and agreement to use the revised tagging likelihood as part of the base case model. This paper presents results for the base case model and agreed robustness trials using sbtmod22. Posterior likelihoods for the base case indicated a strong preference for the higher grid values for steepness and lower value of M_{10}, consistent with initial runs at the OMMP meeting. More detailed analysis of the diagnostics for the base case, however, indicated differences in the preferences among input data sets, particularly across natural mortality and steepness. These results are explored in more detail in Eveson and Davies (2009). Results from the base case, and robustness trials indicate that the SBT is at a low level (3-8% of median unfished spawning stock biomass); the SSB is more likely to have declined in recent years (2004-2008), than increased; that the low recruitments/year classes in the late 1990s and early 2000s previously identified by the ESC as cause for concern, are very low in abundance and have been subject to high fishing mortality. As a result of the above, there is a very low probability that the short-term reference points (designed to reduce risk of further decline in SSB and further weak recruitments) will be achieved under most of the constant catch projections. These results are consistent for the base case and all robustness trials, with the exception of the robustness trial that includes the trolling index of recruitment. The results for the trolling index robustness trial warrant further detailed examination by the ESC, given the issues previously identified with the trolling survey (Anon 2007, 2008).

Introduction

The Commission for the Conservation of Southern Bluefin Tuna (CCSBT) held an inter-sessional meeting (the Operating Model and Management Procedure [OMMP]Technical Meeting, Seattle 2009) to review the structure and fits of the Operating Model (OM) and associated data sets. The outcomes included a revised natural mortality schedule, agreement to incorporate the revised tagging likelihood for the 1990s tagging data and adjusted CPUE series for the reference set, or "base", model and a revised list of robustness trials.

In addition, the work completed at the meeting indicated that the range of steepness values included in the current OM grid may need to be revised. As there was insufficient time at the meeting to complete the analysis required for detailed exploration of the interaction between the revised natural mortality schedule and steepness parameter of the stock-recruitment relationship, the OMMP group requested that this issue be pursued inter-sessionally and results presented for consideration by the Extended Scientific Committee (ESC).

This paper focuses on the fits of the reference set, or "base", model and robustness trials, including the results for the constant catch projections, as agreed at the OMMP meeting for consideration at the September 2009 meeting of the ESC. Further analysis of the interaction between the natural mortality schedules and steepness is provided in Eveson and Davies (2009).

Methods

Base case

The 2008 meeting of the SAG agreed on a base case OM and grid to be used for conditioning the OM in 2009, which was reviewed at the OMMP meeting (2009). 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 grid axes for the new uncertainty grid used for projections was reviewed at the OMMP meeting in Seattle (2009). Based on the results of inter-sessional work at this meeting (Anon 2009), the number of axes was reduced and the new grid is given in Table 1.

The following robustness tests were agreed at the OMMP meeting (2009):

1. Effects of overcatch on *CPUE*: *S* = 0%, 50% and 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. Substitute alternative CPUE series 3 and 6 (as defined in item 11 and Attachment 5 of the Report of the OM and MP Technical Meeting, Seattle 2009).
7. Break *CPUE* into two time series, the second starting in 1986.
8. Use likelihood-based weights for M_1 and M_{10} for grid integration (retain estimation of M_4 and M_{30}).
9. Omega value of 0.75 (CPUE nonlinearity factor).
10. Increase the CV on *CPUE* to 0.30.

Constant catch projections and reference points

All runs of the OM were made using the code provided on 10 August 2009, with data included from the data submission in May 2009, CPUE series from August 2009 and the revised tag likelihood (sbtmod22).

It was agreed at SAG 2008 that management advice in 2009 would be based on constant catch projections from the reconditioned OM and an evaluation of current stock status and recent recruitment based on indicators. This approach is in contrast to a fully developed management procedure (MP) (CCSBT ESC Meeting Report 2008).

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 4 August 2009 version of the code.

Results and Discussion

Model fits for the reference set and robustness trial were explored through examination of overall model preferences across the parameter grid (via the likelihood weights) and likelihood profiles for input data sets and the estimated and/or constrained parameters consistent with the approach taken at the OMMP meeting (Anon 2009). Only summary results and diagnostics to support interpretation of main results and conclusions are included here. The full set of run output and diagnostics will be available on CD for the ESC meeting.

Base case

Consistent with the results from the OMMP meeting (Anon 2009), initial fits of the base case model indicated a strong preference for the two higher steepness values (0.385 not being sampled at all), no preference for M_1 and a general preference for lower M_{10} values (Figure 1). Examination of the likelihood profiles for the individual input data sets revealed a tension in the fits to the different data sources. Fits to the LL4, surface fishery, tagging and aerial survey data generally indicated a preference for high steepness, low M_1 and high M_{10}, while fits to the LL3, Indonesian age data and the overall objective function showed a preference for high steepness and lower M_{10} (Figure 2).

Further exploration of the likelihood profiles for the M schedules and estimated M-vectors from the OM identified that the revised two-stage linear M-function, which includes fixed gridded values for M_1 and M_{10}, can result in a “kink” in the mortality schedule at M_4 for the higher steepness values. This had been considered an undesirable feature at the OMMP meeting, as it is not consistent with general life-history theory or the information on natural mortality for ages 3 and 4 (based on the tagging data). Identification of this issue prompted further detailed investigations of the interaction between the form of the M-function, steepness and the fits to the different input data sets to assess whether the current grid required further revision (see Eveson and Davies 2009).

Hence, the results presented and discussed here are for the base case and grid agreed at the OMMP meeting and these should be considered in the context of the results presented in Eveson and Davies (2009).

In addition to the points noted above with respect to the interaction between steepness and natural mortality, the following points were identified from examination of diagnostics and goodness of fit of a subset of individual fits in the grid:

- as expected there is a correlation between the steepness and natural mortality of the grid;
- analysis of the likelihood profiles indicates that some data sources provide strong signals on natural mortality of the early years classes (e.g. tagging), however there are opposing preferences for steepness among the data sets;
- the nature of the stock trajectory of SBT (continuous decline in spawning biomass with little or no signal of rebuilding) means that there is little “information” in the current data sources to discriminate among the levels of steepness (this has also been the case in past conditioning of the OM).

Given this last point, and the expected correlation between steepness and natural mortality, it may be that the apparent “preference” for different levels of steepness is actually being driven by the relative information content of the different data sets on natural mortality, as opposed to any “real” information on steepness. Obviously, this requires further detailed examination by the Stock Assessment Group (SAG) and ESC.

Robustness Tests

The full range of robustness tests were run and diagnostics and a subset of individual fits examined as for the base case. As noted above a full set of diagnostic plots and fits is available on CD for further examination and discussion at the ESC.

Points worthy of note from initial analysis of detailed diagnostics (likelihood profiles) include:

- the same tension among data sets observed in diagnostics for the base case, in terms of preferences for mortality schedules and steepness (see above and Eveson and Davies 2009), is evident for most robustness trials;
- preliminary examination of fits to the length frequency data sets indicate that there is little difference in the fits to the LL4 data, with most of the "lack of fit" being evident in the estimates of recruits for the other length data sets;
- there is little difference in the diagnostics between the base case and the "zero" overcatch, particularly with respect to the preferences for steepness and mortality schedules (but see Eveson and Davies, 2008)
- the 50% and 75% unreported catch to CPUE scenarios tended to have similar preferences for steepness values across the data sets as the base case but a preference for the lower and mid - M10 values, relative to that seen for the base case.

The robustness trials for the inclusion of the troll survey as an index of recruitment resulted in the most substantial differences of the set of robustness trials.

Two versions were considered: with and without process error. Likelihood profiles, natural mortality vectors and profiles for these robustness tests will be available at the meeting for further examination and discussion. The recruitment predictions by steepness level are shown in Figures 7 and 8 for the tests without and with process error, respectively.

It is evident from these figures that without the inclusion of the process error the model is predicting extremely high recent and future recruitment for this robustness test. Allowing for process error reduces this effect substantially (Figure 8). However, the recruitments are still considerably higher than predicted for the base case and other robustness trials and inconsistent with observations and estimates from the other data sources.

Constant catch projections

Base case

The OM using the base case scenario indicates that the current median spawning biomass is approximately 0.05 of the estimated unfished level (0.03-0.07; 80% CI) of the estimated median unexploited spawning biomass (Table 2, Figure 9).

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

- the probability that the median spawning biomass in 2014 will be lower than 2004 or 2008, is very high (ranging from 92% and 98%, respectively, for current TAC, and up to 100% for a 4000 t increase above current TAC);

For the constant catch scenarios of reductions in catches of 4000 t or less below the current TAC the probability of spawning biomass in 2014 being the lower than the estimated 2004 or 2008 spawning biomass are:

- 67% and 68%, for 2004 and 2008, respectively, if the catch is 4000 t less than the current TAC;
- 85% and 88%, for 2004 and 2008, respectively, if the catch is 2000 t less than the current TAC;

For the zero catch scenario:

- the probability of the spawning biomass in 2014 being lower than the estimated 2004 or 2008 spawning biomass is low, 20% and 7%, respectively.

Robustness Trials

Table 3 provides a summary of the results for each of the reference points for the agreed robustness trials, where constant catch projections have been made using the current TAC.

In terms of current stock status and impacts of the different future catch scenarios, the results are consistent across robustness trials with the notable exception of the trial that includes the trolling index, and indicate:

- estimated current depletion of median spawning biomass ranges between 0.02 and 0.08;
- the probability of median spawning biomass in 2014 being greater than the estimated 2004 or 2008 biomass for future catches equal to the current TAC is very low (less than 10%) for all robustness trials, with the exception of the scenario that includes the trolling index as a measure of recruitment.

Conclusions

The following conclusions can be drawn from these results:

- Consistent with 2006 and 2008 conclusions of the ESC, the results from the re-conditioned OM indicate that the SBT stock is at a low level (3-8% of median unfished spawning biomass).
- The spawning stock biomass of SBT appears more likely to have declined in recent years (2004-2008) than increased.
- That the low abundance year classes in the late 1990s and early 2000s previously identified by the ESC as cause for concern (Anon 2005, 2006, 2007, 2008), are very low in abundance and have been subject to high fishing mortality.
- As a result of the above, there is a low probability that the short-term reference points (designed to reduce risk of further decline in spawning biomass and further weak recruitments) will be achieved under most of the constant catch projections.
- These results are consistent for the base case and all robustness trials, with the exception of the robustness trial that includes the trolling index of recruitment;
- While there were differences in the quality of fits and model diagnostics for each of the CPUE unreported catch scenarios, the impact of these on results for current stock status and future catch projections was small. In particular, there was little substantive difference between the base case (0.25CPUE) and the zero impact of overcatch on reported CPUE scenario, while the fits for the higher proportions of overcatch being attributed to reported effort were poorer;
- The results for the trolling index robustness trial warrant further detailed examination by the ESC given the issues previously identified with the troll survey (Anon 2007, 2008).

Acknowledgements

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Tables

Table 1. The grid as agreed at the OMMP Technical Meeting, Seattle 2009.

	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	2	6	0.3, 0.35	uniform	likelihood
M10	3	18	0.07, 0.1, 0.14	uniform	likelihood
Omega	1	18	1	NA	NA
CPUE	2	36	w.5, w.8	uniform	prior
q age-range	2	72	4-18, 8-12	0.67, 0.33	prior
Sample size	1	72	SQRT	NA	NA

Table 2. Summary of results of base case projections against agreed reference points.

TAC zero	10%	30%	50%
B2014/B2004	0.94	1.16	1.21
B2014/2008	1.00	1.18	1.22
B2022/B2004	1.40	2.16	2.50
B2022/B2008	1.52	2.20	2.55
B2022/B2010	1.59	2.22	2.58
B2025/B2010	1.82	2.75	3.28
B2008/B0	0.03	0.04	0.05
B2008/B1980	0.13	0.17	0.18
P(B2014>B2004)	0.80		
P(B2014>B2008)	0.93		

TAC -4000	10%	30%	50%
B2014/B2004	0.79	0.88	0.95
B2014/2008	0.86	0.92	0.96
B2022/B2004	0.59	0.85	1.10
B2022/B2008	0.64	0.88	1.12
B2022/B2010	0.69	0.94	1.19
B2025/B2010	0.64	1.00	1.33
B2008/B0	0.03	0.04	0.05
B2008/B1980	0.13	0.17	0.18
P(B2014>B2004)	0.33		
P(B2014>B2008)	0.32		

TAC -2000	10%	30%	50%
B2014/B2004	0.72	0.80	0.87
B2014/2008	0.78	0.85	0.89
B2022/B2004	0.28	0.55	0.76
B2022/B2008	0.31	0.57	0.78
B2022/B2010	0.34	0.61	0.84
B2025/B2010	0.13	0.53	0.82
B2008/B0	0.03	0.04	0.05
B2008/B1980	0.13	0.17	0.18
P(B2014>B2004)	0.15		
P(B2014>B2008)	0.12		

TAC current	10%	30%	50%
B2014/B2004	0.62	0.73	0.80
B2014/2008	0.68	0.77	0.82
B2022/B2004	0.00	0.24	0.44
B2022/B2008	0.00	0.26	0.45
B2022/B2010	0.00	0.28	0.49
B2025/B2010	0.00	0.01	0.33
B2008/B0	0.03	0.04	0.05
B2008/B1980	0.13	0.17	0.18
P(B2014>B2004)	0.08		
P(B2014>B2008)	0.02		

TAC +2000	10%	30%	50%
B2014/B2004	0.50	0.65	0.73
B2014/2008	0.55	0.68	0.75
B2022/B2004	0.00	0.00	0.13
B2022/B2008	0.00	0.00	0.13
B2022/B2010	0.00	0.00	0.15
B2025/B2010	0.00	0.00	0.00
B2008/B0	0.03	0.04	0.05
B2008/B1980	0.13	0.17	0.18
P(B2014>B2004)	0.03		
P(B2014>B2008)	0.00		

TAC +4000	10%	30%	50%
B2014/B2004	0.37	0.56	0.65
B2014/2008	0.40	0.58	0.66
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	0.03	0.04	0.05
B2008/B1980	0.13	0.17	0.18
P(B2014>B2004)	0.00		
P(B2014>B2008)	0.00		

Table 3. Summary of results of constant catch projections of current TAC for each robustness test against agreed reference points.

Scenario	B2014/B2004			B2014/B2008			B2022/B2004			B2022/B2008		
	10%	30%	50%	10%	30%	50%	10%	30%	50%	10%	30%	50%
Base	0.62	0.73	0.80	0.68	0.77	0.82	0.00	0.24	0.44	0.00	0.26	0.45
CPUE S=0	0.62	0.71	0.78	0.68	0.75	0.80	0.00	0.14	0.36	0.00	0.15	0.37
CPUE S=0.5	0.63	0.76	0.83	0.69	0.79	0.84	0.00	0.35	0.54	0.00	0.37	0.55
CPUE S=0.75	0.65	0.79	0.85	0.71	0.81	0.85	0.11	0.44	0.63	0.12	0.45	0.64
LL1 Case 2 of MR	0.69	0.78	0.85	0.75	0.82	0.87	0.08	0.36	0.55	0.09	0.38	0.56
Uncorrelated RDs	0.56	0.63	0.69	0.62	0.69	0.75	0.00	0.00	0.24	0.00	0.00	0.26
Include Troll	0.85	0.99	1.02	0.93	1.02	1.04	2.47	3.36	4.07	2.62	3.45	4.14
Truncate CPUE	0.05	0.15	0.20	0.07	0.21	0.30	0.00	0.00	0.00	0.00	0.00	0.00
Alternative CPUE	0.56	0.62	0.68	0.62	0.69	0.74	0.00	0.00	0.18	0.00	0.00	0.20
Break CPUE	0.63	0.71	0.77	0.68	0.75	0.80	0.00	0.16	0.36	0.00	0.17	0.37
Priors for M1, M10	0.63	0.73	0.79	0.68	0.76	0.81	0.00	0.25	0.45	0.00	0.26	0.45
Omega=0.75	0.55	0.62	0.68	0.61	0.68	0.74	0.00	0.00	0.17	0.00	0.00	0.18
CPUE CV=0.3	0.53	0.64	0.70	0.61	0.71	0.77	0.00	0.03	0.25	0.00	0.03	0.27

Scenario	B2022/B2010			B2025/B2010			B2008/B0			B2008/B1980		
	10%	30%	50%	10%	30%	50%	10%	30%	50%	10%	30%	50%
Base	0.00	0.28	0.49	0.00	0.01	0.33	0.03	0.04	0.05	0.13	0.17	0.18
CPUE S=0	0.00	0.16	0.41	0.00	0.00	0.19	0.03	0.04	0.05	0.11	0.13	0.15
CPUE S=0.5	0.00	0.39	0.59	0.00	0.19	0.49	0.04	0.05	0.06	0.14	0.20	0.21
CPUE S=0.75	0.13	0.49	0.68	0.00	0.36	0.63	0.04	0.06	0.07	0.16	0.23	0.26
LL1 Case 2 of MR	0.10	0.41	0.61	0.00	0.21	0.50	0.04	0.05	0.05	0.13	0.17	0.18
Uncorrelated RDs	0.00	0.00	0.29	0.00	0.00	0.00	0.02	0.03	0.03	0.10	0.11	0.13
Include Troll	2.92	3.90	4.71	2.71	3.65	4.44	0.06	0.07	0.08	0.16	0.20	0.23
Truncate CPUE	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.07	0.07	0.08
Alternative CPUE	0.00	0.00	0.22	0.00	0.00	0.00	0.02	0.03	0.03	0.10	0.11	0.13
Break CPUE	0.00	0.19	0.40	0.00	0.00	0.18	0.03	0.04	0.05	0.13	0.15	0.16
Priors for M1, M10	0.00	0.29	0.50	0.00	0.03	0.35	0.03	0.05	0.06	0.13	0.17	0.19
Omega=0.75	0.00	0.00	0.20	0.00	0.00	0.00	0.02	0.03	0.03	0.10	0.11	0.13
CPUE CV=0.3	0.00	0.03	0.30	0.00	0.00	0.04	0.03	0.04	0.04	0.12	0.16	0.17

Scenario	Pr(B2014>B2004)	Pr(2014>B2008)
Base	0.08	0.02
CPUE S=0	0.08	0.02
CPUE S=0.5	0.08	0.02
CPUE S=0.75	0.09	0.01
LL1 Case 2 of MR	0.13	0.07
Uncorrelated RDs	0.07	0.02
Include Troll	0.66	0.78
Truncate CPUE	0.00	0.00
Alternative CPUE	0.06	0.02
Break CPUE	0.07	0.01
Priors for M1, M10	0.05	0.01
Omega=0.75	0.05	0.01
CPUE CV=0.3	0.01	0.00

Figures

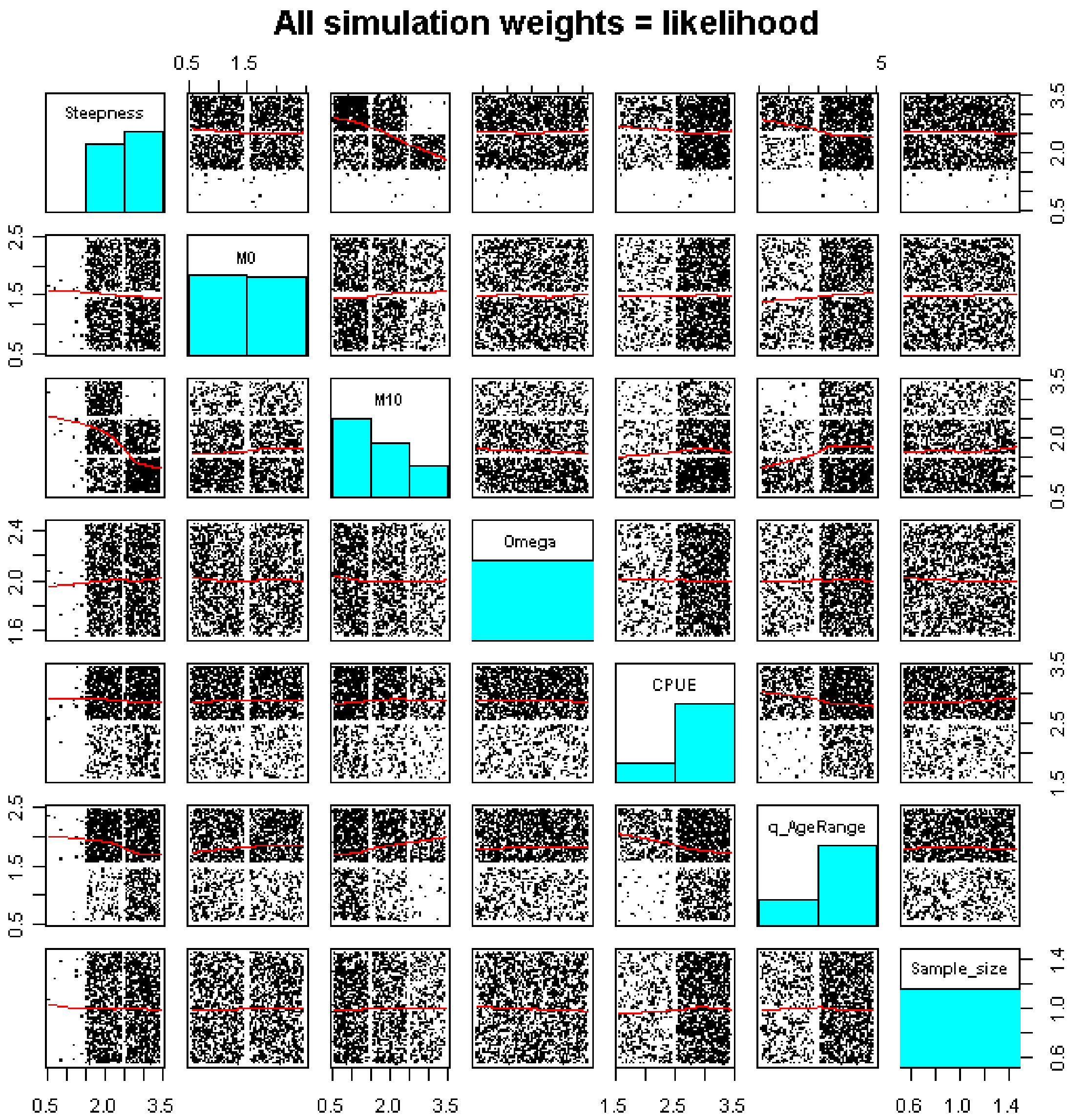
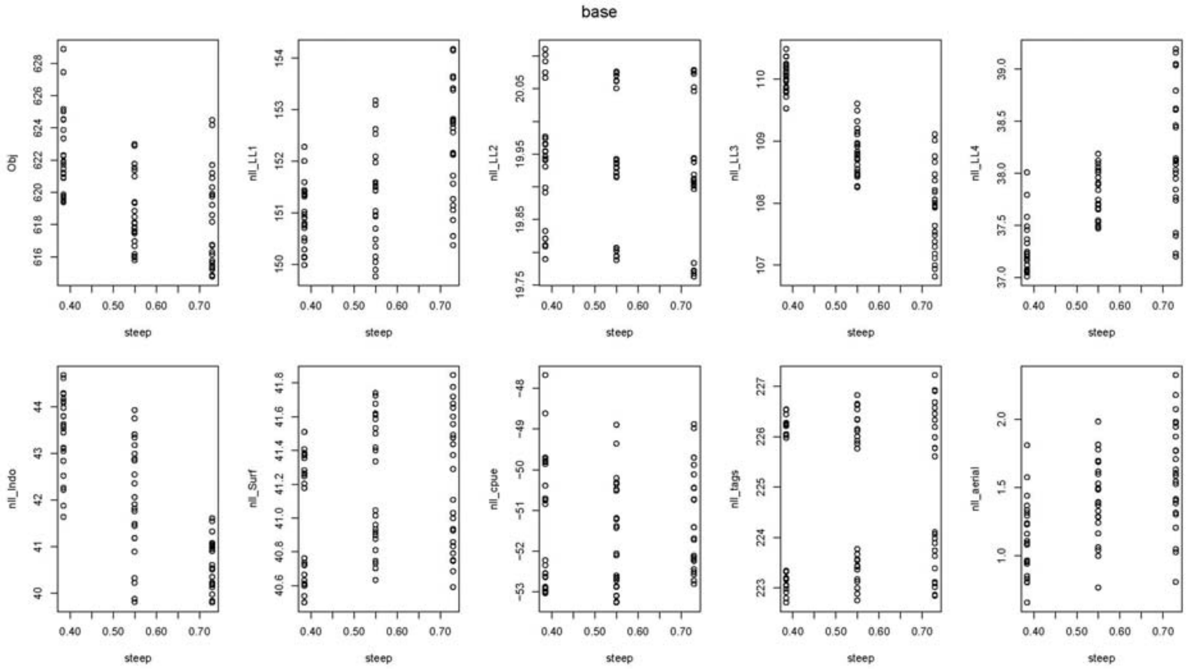
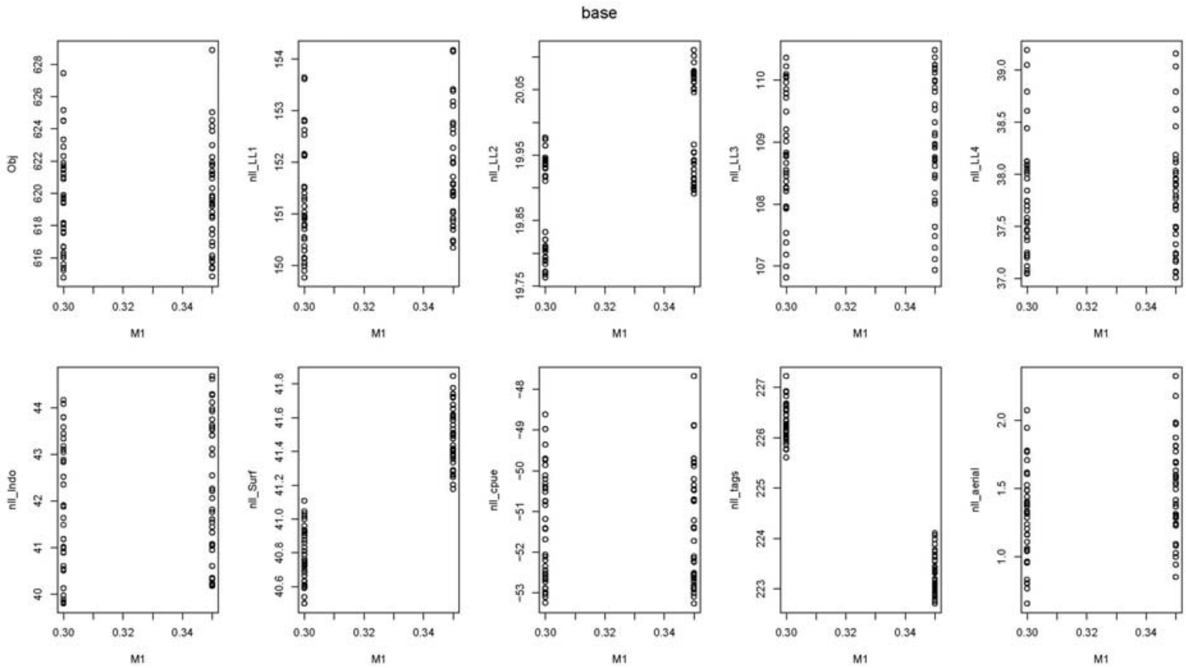


Figure 1. Shade plot of for base case model using posterior NLL weights.

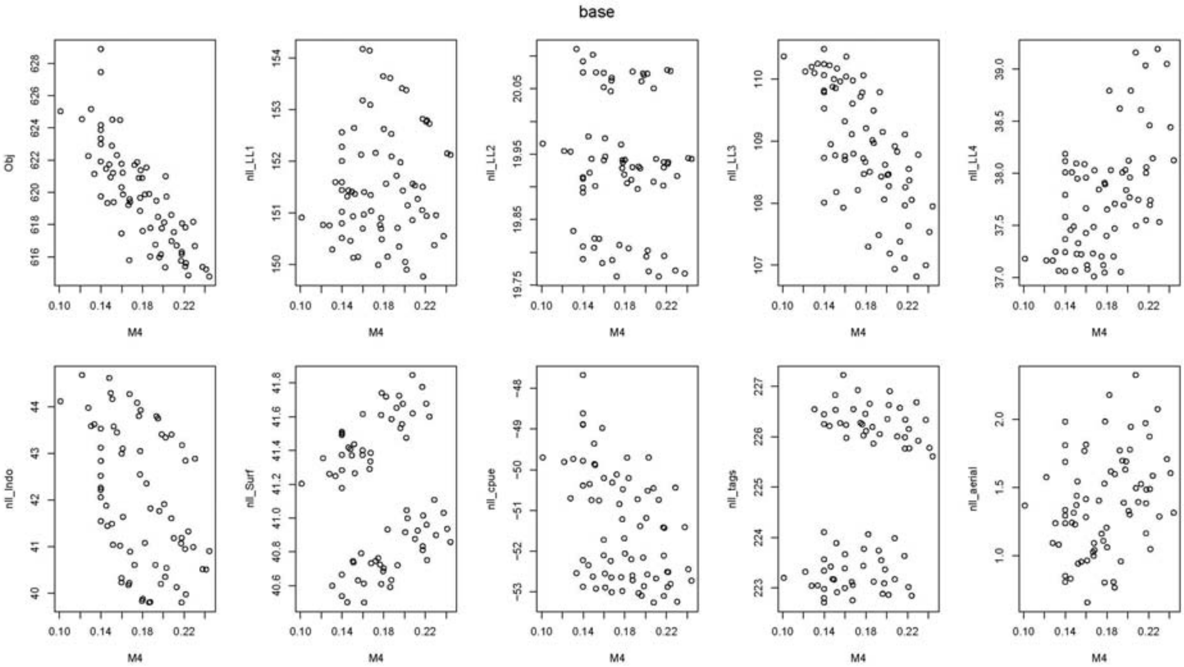


a) Steepness

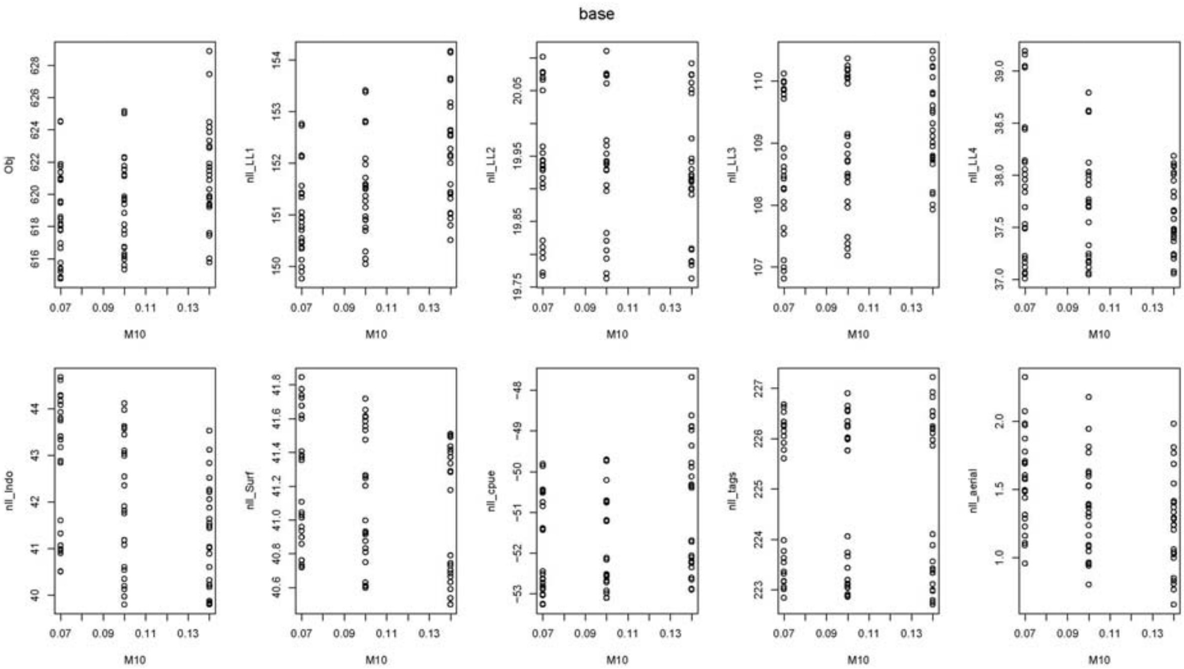


b) M1

Figure 2. Individual likelihood profiles for fitted data sets for base case for a) steepness, b) M1, c) M4, d) M10, e) M30, f) C and g) a.

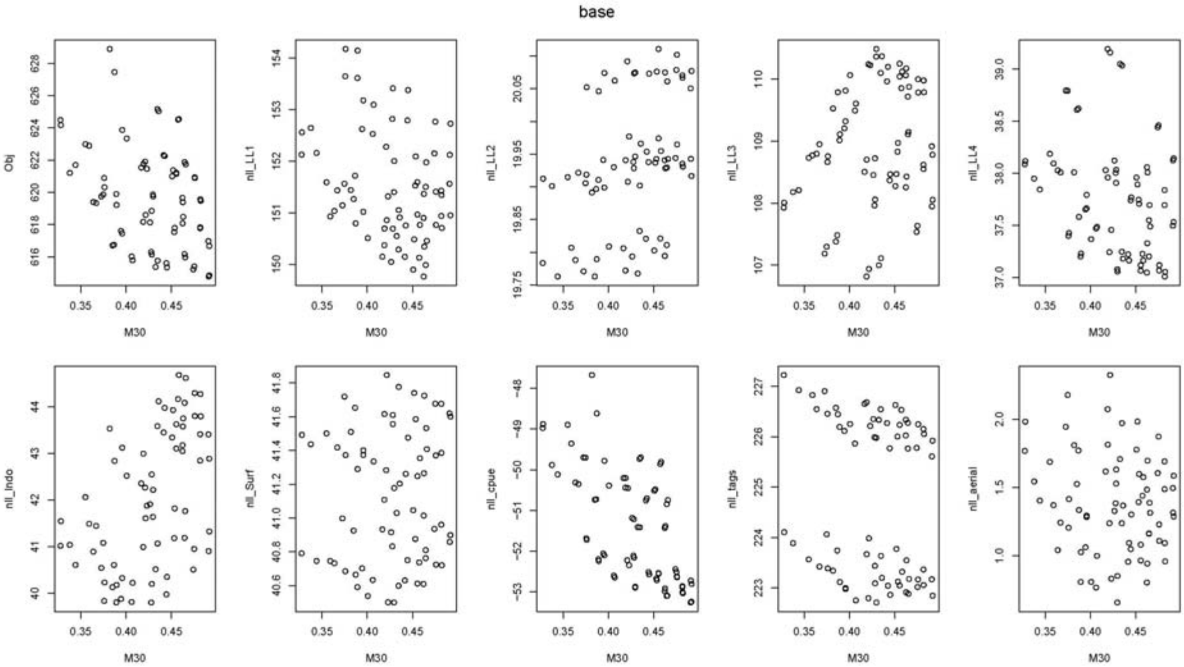


c) M4

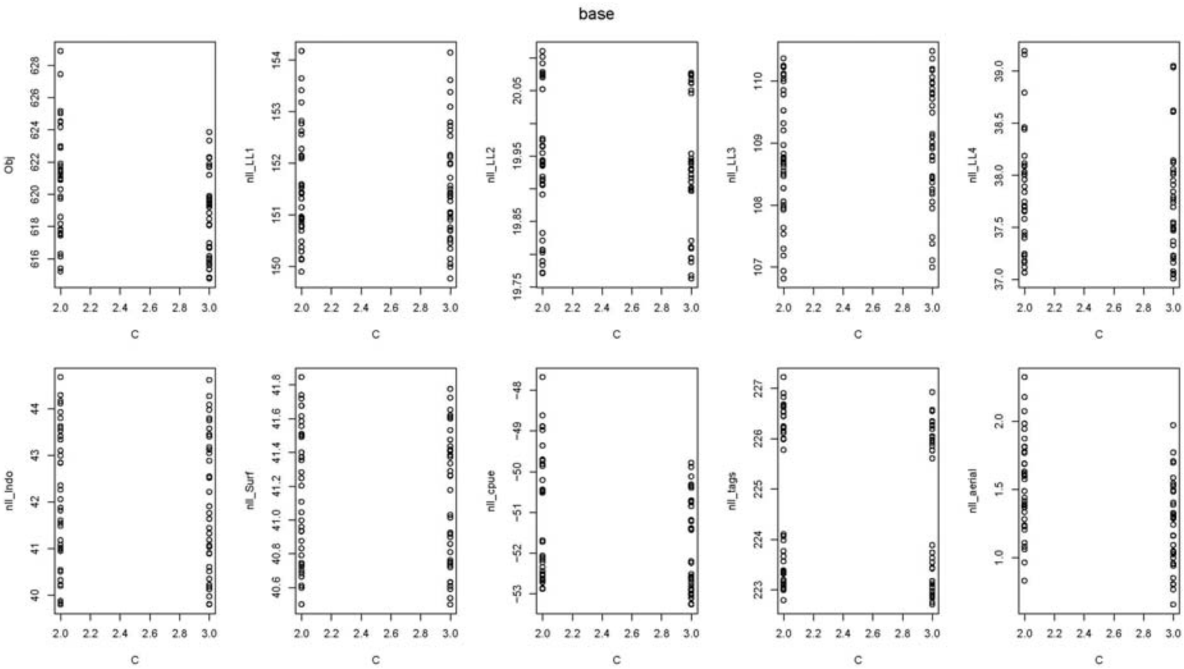


d) M10

Figure 2 (continued). Individual likelihood profiles for fitted data sets for base case for a) steepness, b) M1, c) M4, d) M10, e) M30, f) C and g) a.

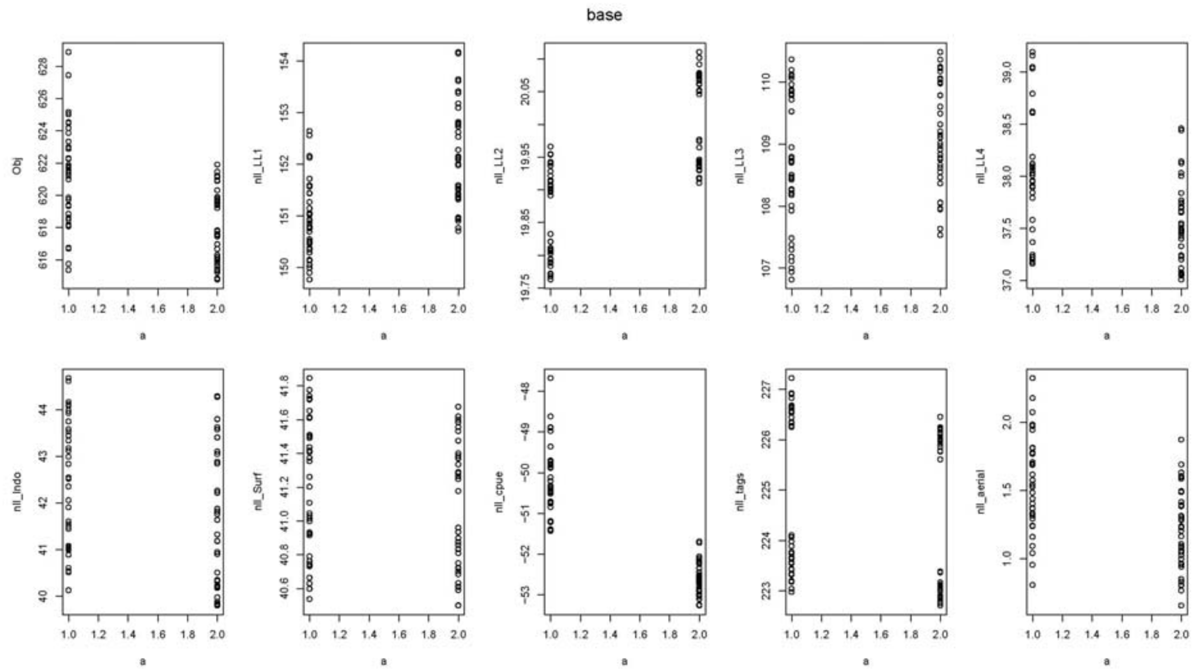


e) M30



f) C

Figure 2 (continued). Individual likelihood profiles for fitted data sets for base case for a) steepness, b) M1, c) M4, d) M10, e) M30, f) C and g) a.



g) a

Figure 2 (continued). Individual likelihood profiles for fitted data sets for base case for a) steepness, b) M1, c) M4, d) M10, e) M30, f) C and g) a.

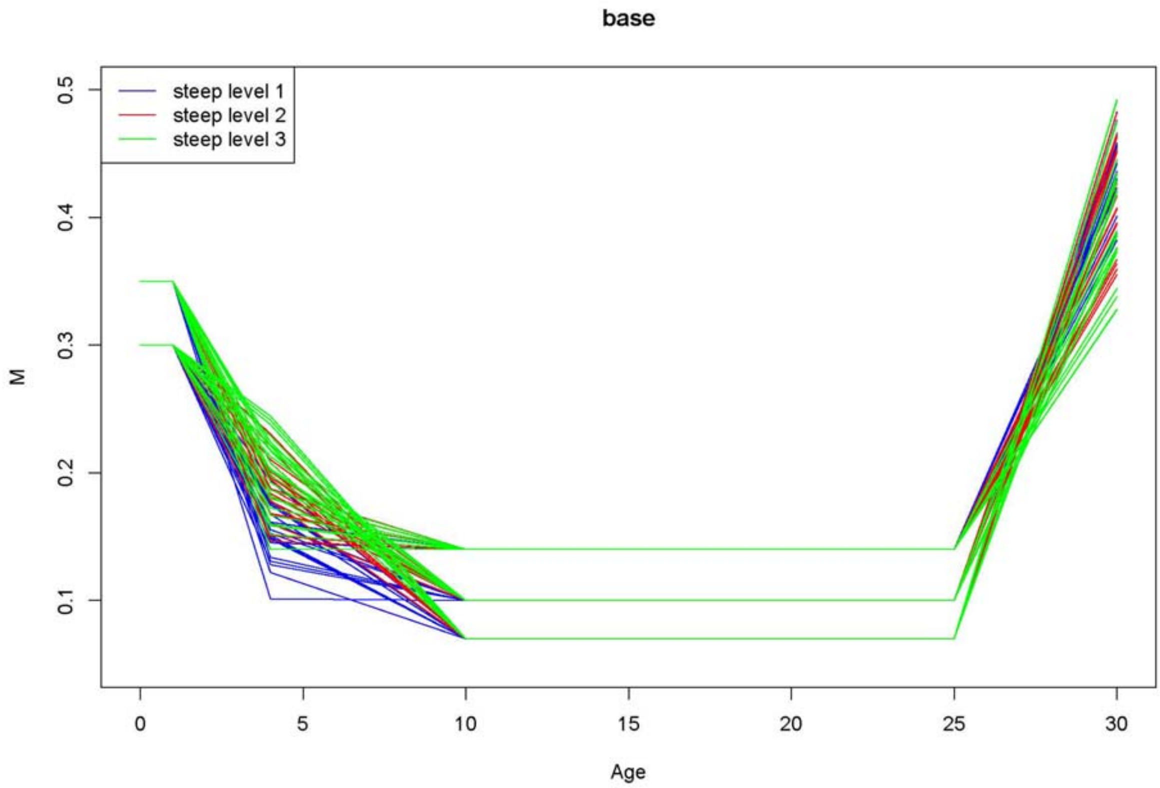


Figure 3. Natural mortality vectors for base case by level of steepness.

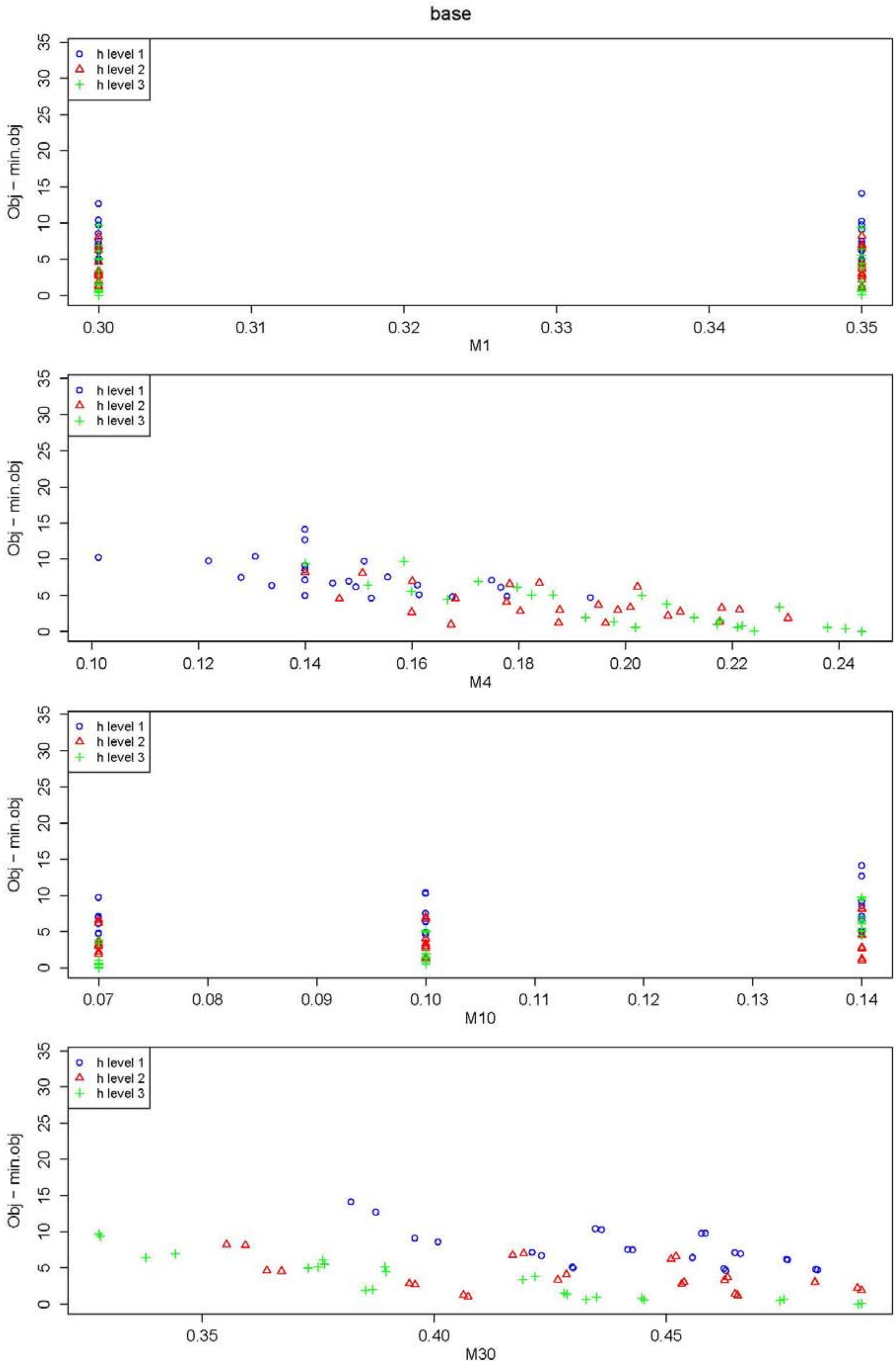
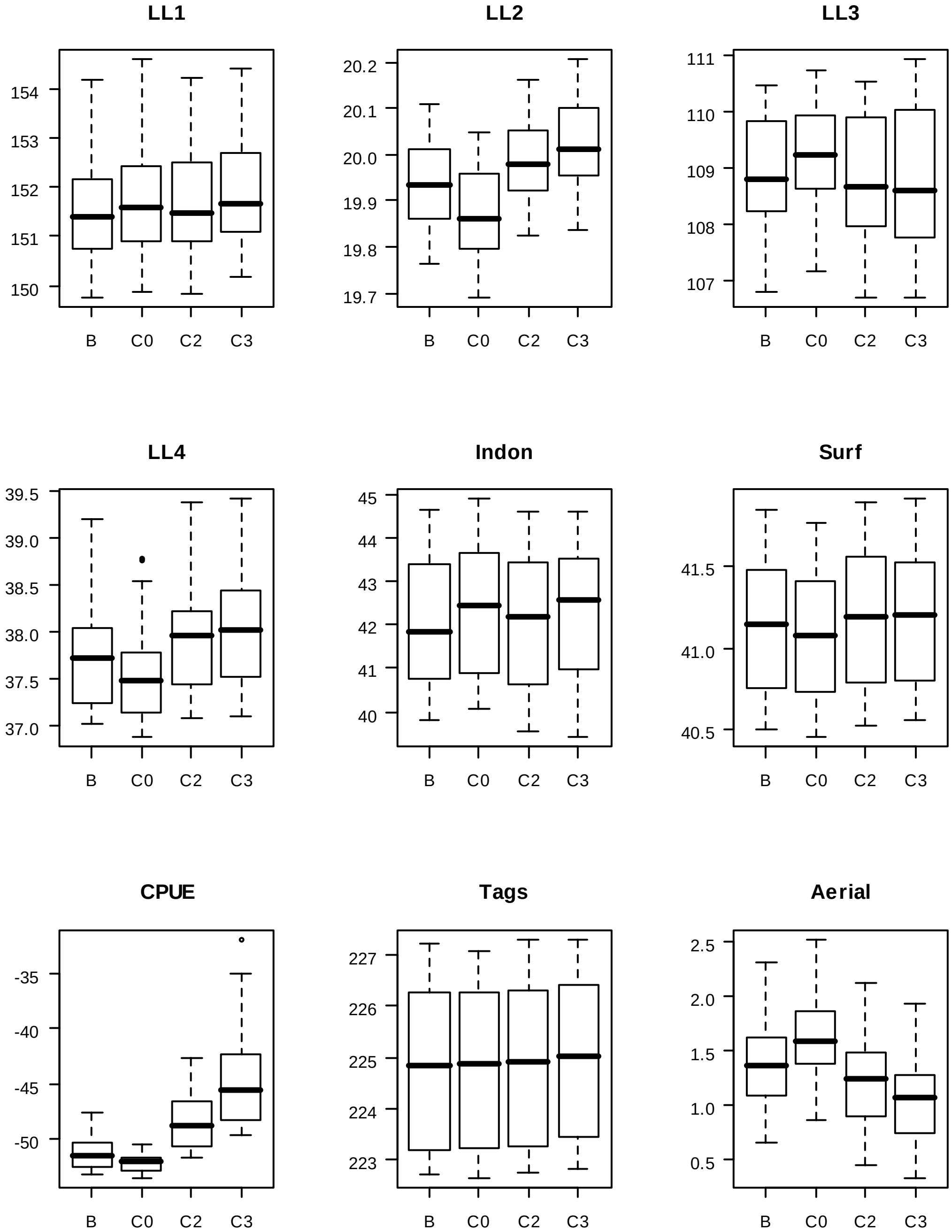


Figure 4. Likelihood profiles for levels of M1 and steepness for base case.



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

Figure 5. Boxplots of likelihoods for fits to individual data sets for base case and three overcatch scenarios.

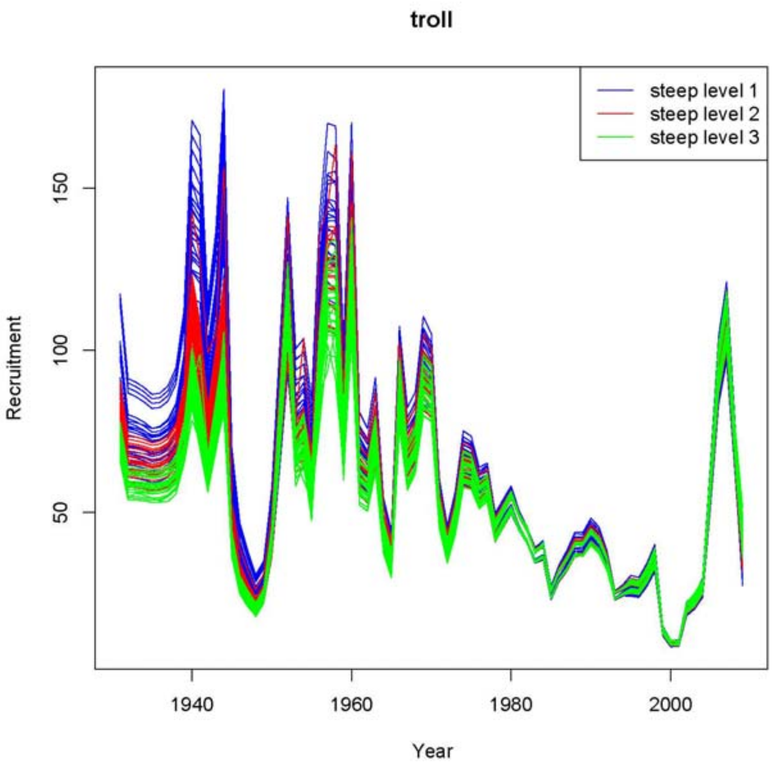


Figure 6a). Recruitment predictions for inclusion of troll survey robustness trial (without process error).

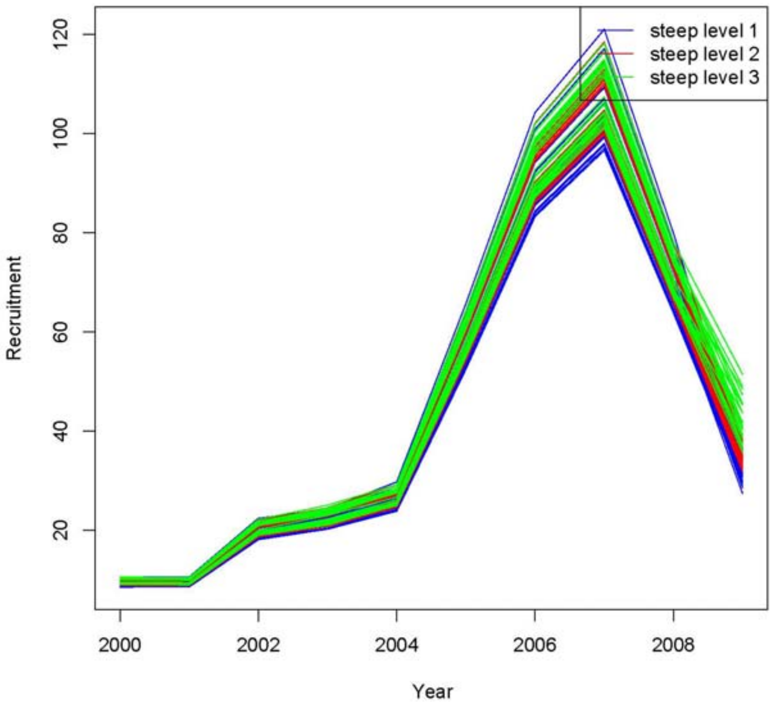


Figure 6b). Recruitment predictions for inclusion of troll survey robustness trial (without process error) for recent period.

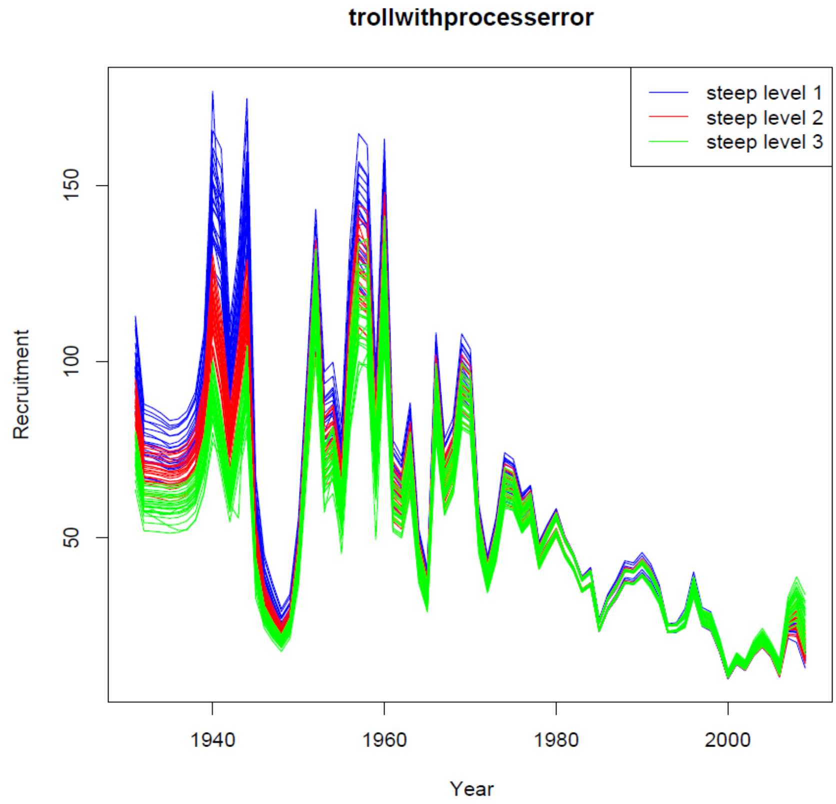


Figure 7a). Recruitment predictions for inclusion of troll survey robustness trial (with process error).

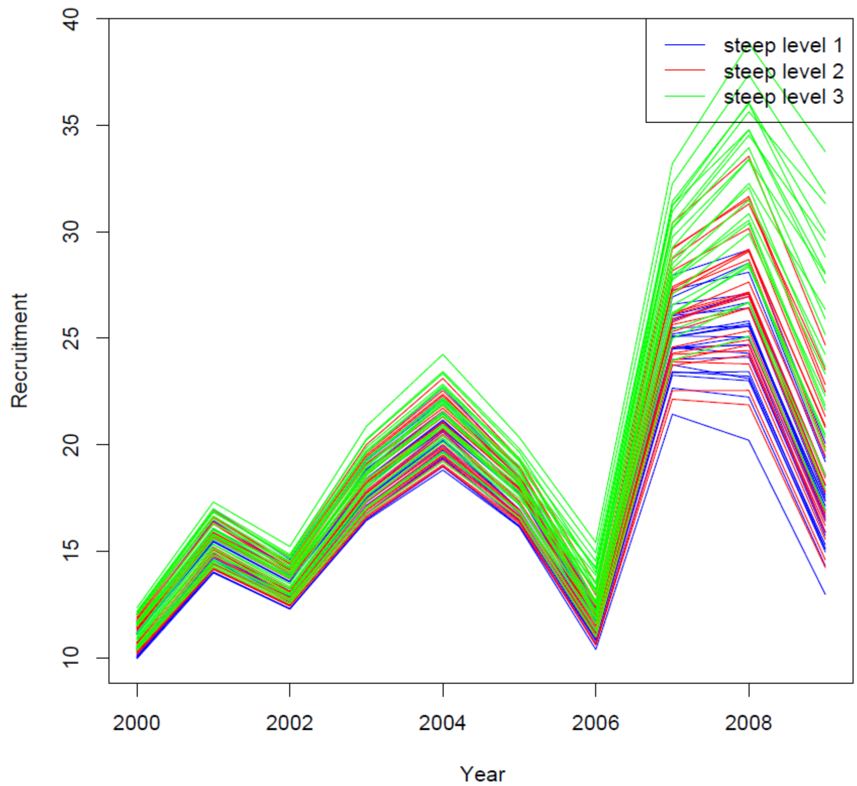
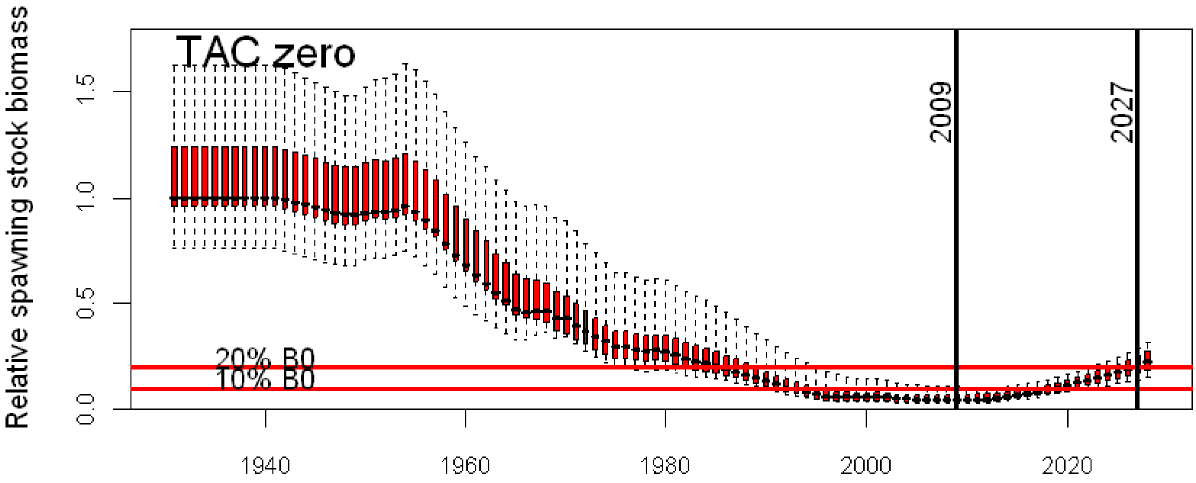
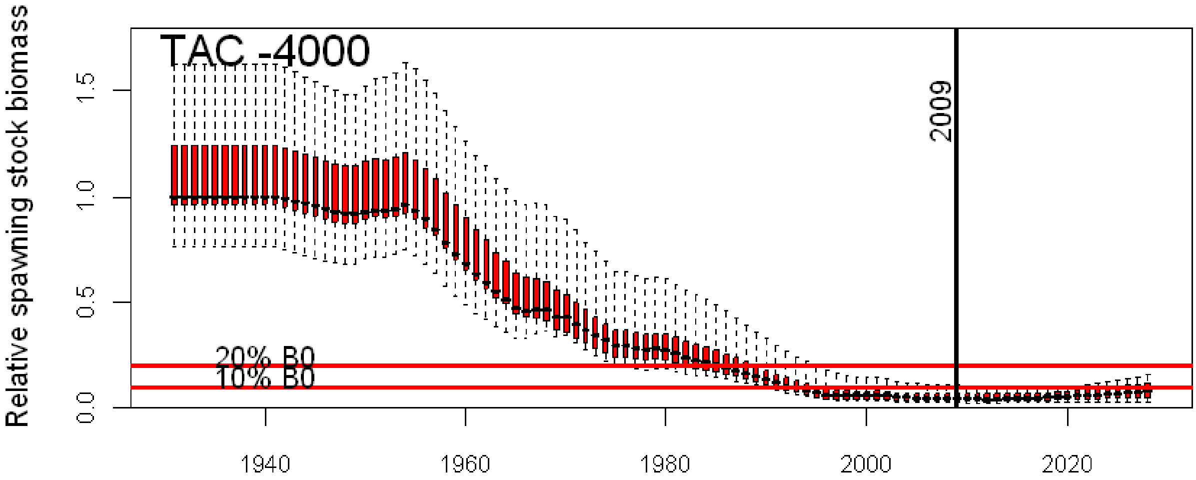
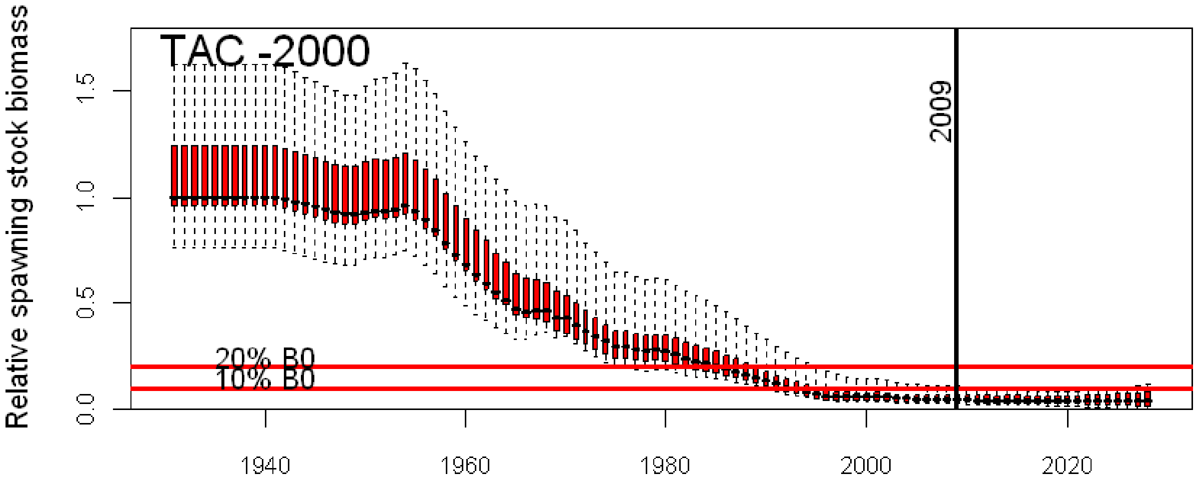


Figure 7b). Recruitment predictions for inclusion of troll survey robustness trial (with process error) for recent period.


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


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


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

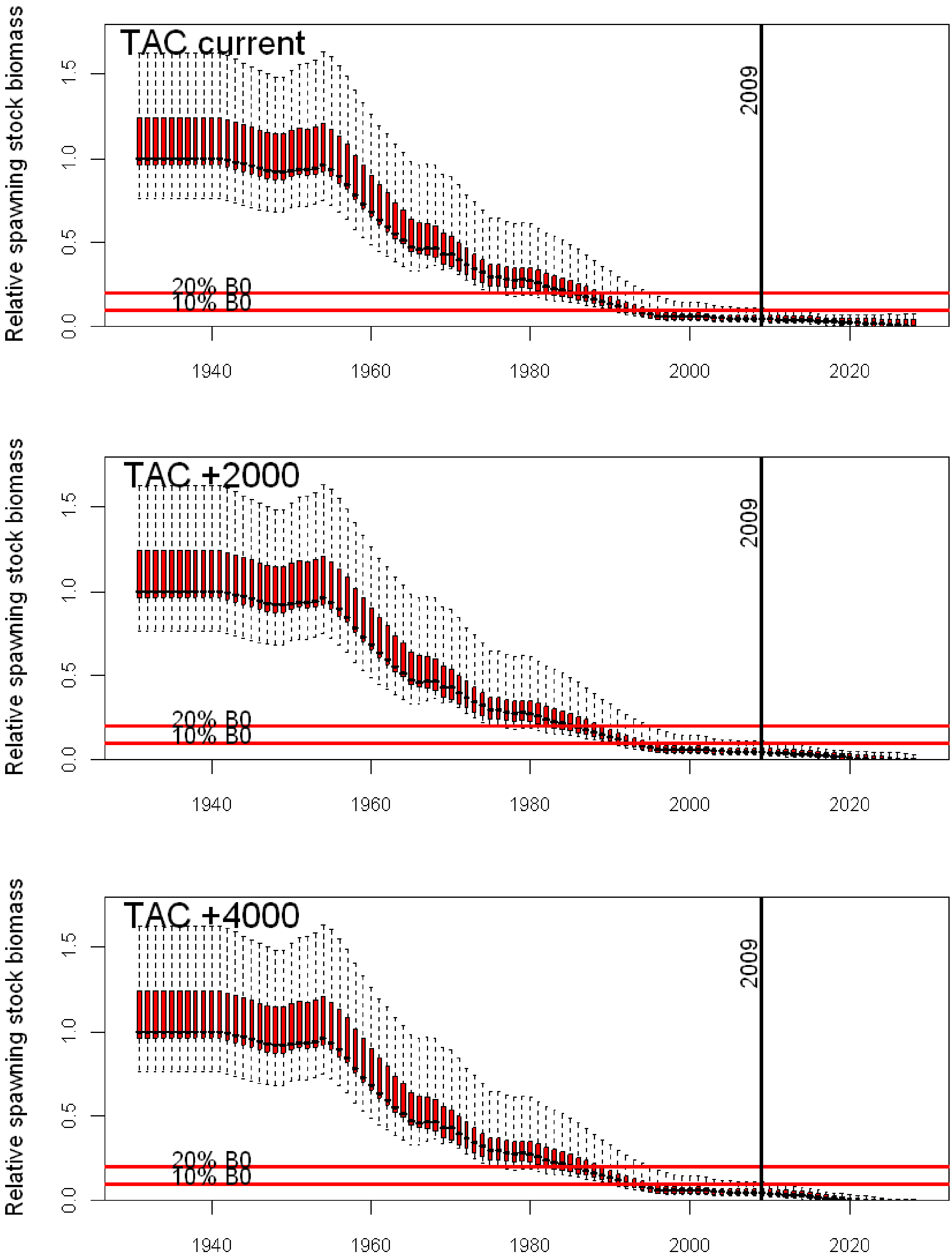


Figure 8. Model projections of relative spawning stock biomass (SSB) for the base case integrated over the grid agreed at the OMMP meeting (Anon 2008) for each of the constant catch levels (± 2000, 4000, current, and zero).