Commission for the Conservation of Southern Bluefin Tuna

みなみまぐろ保存委員会

Report of the Operating Model and Management Procedure Technical Meeting

13 - 17 July 2009
Seattle, USA

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Opening

1. The Chair of the Operating Model and Management Procedure (OMMP) Technical Working Group (WG), Dr. Ana Parma opened the meeting and welcomed participants.
2. Participants introduced themselves. The list of participants is at **Attachment 1**.
3. The chair drew the attention of the WG to the Terms of Reference of the OMMP (**Attachment 2**) and asked for any changes to the proposed agenda. The draft agenda was adopted. The WG noted they expected to make little progress on agenda item 4 (Future MP work) at this meeting given the priority to finalise the operating model.
4. No additional documents had been received to those listed in **Attachment 3**. By prior agreement the meeting was paperless with all documents available on the CCSBT website. Dr Kevin Sullivan agreed to co-ordinate the preparation of the report.

Agenda Item 1. Inputs to the Operating Model

1.1 Historical catches and size compositions

5. In 2008 the Stock Assessment Group (SAG) agreed that if new information that is more reliable becomes available, then it will be used in conditioning the OM. No new data were presented at this meeting so the catches agreed at the last SAG will be used in OM runs between now and the September SC meeting (see **Attachment 4** for details about overcatch scenarios).
6. A paper evaluating the market for the last three years is being prepared for the SC. However, any changes in the catch history that may result from this study were not expected to have substantial impacts on the OM conditioning or constant catch projections.

1.2 CPUE scenarios

CPUE series

7. The CPUE WG had met twice inter-sessionally and had supplied two base CPUE series for the current OM. From the standardized CPUE using the method described in Takahashi (2006), CPUE series based upon constant square area weighting and variable square area weighting were first produced. In turn these were combined as two weighted mean series (w0.5 and w0.8) to provide two "new" 1986-2006 series.

8. There are two alternatives available to link the earlier series before 1986 with more recent data, either calibrate the difference in CPUE and provide one continuous CPUE series or split the series and estimate separate catchability coefficients in the model pre- and post-1986. The difference between the two is likely to influence the estimate of the level of long term depletion.

9. To provide data prior to 1986 two equivalent series were calculated using the above statistical model but with the bycatch terms omitted (as these are not available for data prior to 1986). These were fitted to all Japanese vessels between 1969 and 2006 in the CCSBT data base to provide two "old" 1969-2006 series.

10. The two CPUE series were combined for w0.5 and w0.8 as follows:
    - CPUE 1969-1985: As in the "old" 1969-2006 series.
    - CPUE 1986-2006: As in the "new" 1986-2006 series*constant, where constant = {average "old" series (1986-2006)}/ {average "new" series (1986-2006)}.

11. The two new CPUE series (w.5 and w.8) will be used as the reference set and be given equal weight. Other CPUE series may be used in robustness trials. However, the WG agreed that the 5 older CPUE series are no longer relevant and that any robustness trial should show a different pattern of CPUE than the reference set in order to provide contrast. The group reviewed paper CCSBT-CPUE/0907/WP06, where different methods of adjusting for non-SBT targeting were investigated. From the runs shown in this paper the CPUE WG chose run 3 and run 6 for robustness trials (see **Attachment 5**).

12. Run 3 (where targeting was taken into account by a categorical variable with percentage of hauls with presence of bycatch) shows differences from the base case CPUE series at the end of the series. Run 6 models the main effects used in the base series on operations where only SBT was caught and shows differences in the earlier part of the CPUE series. It was also agreed that the model used in run 4 (where continuous variables of the percentage of hauls without bycatch tunas was included), as it had a similar trend to the base, would be used to monitor the base series into the future

Post 2006 CPUE data

13. The WG discussed how to deal with CPUE for the most recent year. The WG agreed that the time lag in the availability of logbook data (up to two years) means that the RTMP data may need to be used in the MP.

14. RTMP data are available for the core vessels (i.e. Japanese allocated SBT quota vessels) but a comparison of RTMP and logbook data (CCSBT-CPUE/0907/WP04) showed that in previous years RTMP overestimated CPUE for the logbook data (particularly for area 4). The group agreed that the comparison of RTMP and logbook data should be for the same core vessels and should be recalibrated for years following the introduction of the new management regime (post 2006) to the standardised CPUE values. The variance of the ratio (RTMP/logbook) is required as this variability adds to that between observations and underlying abundance which needs to be taken into account when OMs are used to generate data for MP testing.

Review of inter-sessional papers presented at the web meetings

15. CCSBT-CPUE/0907/WP03 was presented to the WG. The paper looked at the effect on standardised CPUE by dividing the data into length rather than age classes. CPUE by size class showed the expected progression of cohorts through the fishery and the sum of all the size classes matched the pattern seen in the age 4+ indices. Because of this similarity the size based CPUE series were not seen as suitable for a robustness trial for the reference set, but may be worth exploring further from a monitoring perspective.

16. CCSBT-CPUE/0907/WP04 was presented to the WG. As for many previous studies this showed some differences between observed and non-observed catch rates for some years. A robustness test was suggested where the base CPUE series was scaled by the ratio of the indices of the series corresponding to observed sets, to the indices of the series corresponding to unobserved sets, in the period where there was the most difference (1994-2000). Elsewhere the series would not be scaled (i.e. S = 0%). It was agreed that further work should be carried out on these data (**Attachment 5**) before considering to use the result further in robustness testing.

2.2 Other data inputs

17. The WG agreed to review the growth data (i.e. weight at age and length at age) used in the OM. The current model has size information in two seasons (January and July) and specifies the blocks of years to use for each set. It was pointed out that analyses already carried out on the 1960 to 2000 data have not been incorporated (Polacheck et al. 2004). Future work may involve preparing a paper on the length and weight at age.

18. The WG reviewed the base inputs agreed at SAG 9:

- *LL1* overcatch scenario based on Case 1 of the market review report.
- Surface fishery overcatch scenario of 20%.
- *CPUE* scenario S = 25% (25% of the unreported catch attributed to the *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.

19. The only intersessional changes to the reference case in 2009 were a new model structure for the tagging data and the inclusion of the covariance estimates for the aerial surveys (see **Attachment 6**).

Post-2000 tag data

20. This is a data source that is not currently used in the OM. The tag data have been used to estimate fishing mortality outside the model and can be used by the SAG and SC as a relative abundance index and recruitment indicator. The WG supported the incorporation of the more recent tagging data in the OM or as an independent test of the OM. However, the WG recognized that this is unlikely to

happen in the near term until certain features (e.g., the low proportions of returns of age 1 SBT tagged off of WA) of these data are better understood.

Agenda Item 2. Reconsideration of Operating Models

2.1 Review of inter-sessional analyses conducted by national scientists

21. CCSBT-OMMP-0907/04 presented a subset of the robustness trials identified at the SAG technical meeting held in September 2008. The main change seen in the results using the new tag model structure was to the parameter omega (non-linearity of the CPUE). M did not change much but the CPUE negative log likelihood component increased as the CPUE scaling increased beyond S = 25%, suggestive of increasingly poor fits to the CPUE. There was little difference between the cases of S = 0% and S = 25%.

22. CCSBT-OMMP-0907/05 presented a comparison of the results from models sbtmod21 and sbtmod22. The analyses showed:

- The new tagging likelihood incorporated in sbtmod22 led to higher M_0, lower M_{10} and lower omega estimates than the previous model.
- Assumptions regarding the Indonesian fishing selectivity impacted on M estimates substantially. The high abundance of old fish for low natural mortalities seemed inconsistent with the Indonesian catch-at-age data. To address this problem the Indonesian fishing selectivity for age 29 was assumed to be equal to that for age 30+. This change had a considerable impact on results, irrespective of the tagging model applied.

2.2 Consideration of additional estimation trials and model diagnostics performed/evaluated during the meeting

23. A number of estimation trials were carried out and changes made to the model structure and parameterisation based on the results shown in **Attachment 7**.

Natural mortality and plus group considerations

24. The WG discussed how to reconcile the disproportionate abundance of the plus group in the model for low M and explored a number of options, including senescent mortality for age 30+ fish. In this way the size of the plus group with the low M values in the grid could be reduced to levels more consistent with the age data seen in the Indonesian fishery. The WG used the relative values of the likelihood contribution from each component to choose between alternative model structures but also used the shape of the selectivity curve for the Indonesian fishery as a diagnostic test. The natural mortality schedule was modified so that the selectivity appears more reasonable compared to previous estimation trials (details are discussed in **Attachment 7**). The final choice involved setting the selectivity constant from age 25 onwards and estimating the M value for the plus group within the model. The value of M (for 30+ ages) was inversely correlated with M for younger ages.

25. Considerations of results for alternative values of M_{10} suggested that the current default of three values (0.07, 0.10, and 0.14) should be retained with likelihood-based weightings. See also paragraph 31.

Natural mortality on young ages

26. During investigative trials fitting natural mortality for young ages the WG found that the value of M for ages older than the 0 group appeared to be too high to be consistent with the data. The resolution of this problem involved estimating natural mortality at age 4 and changing the assumptions of the model with respect to the functional form of the M schedule (see **Attachment 6**). The tagging data appeared to give strong signals on the value of M for these young age classes in the new sbtmod22 model.

27. In addition to estimating the value of M at age 4 in the model, two values of M were assumed at age 1 (0.3, and 0.35 following testing of values which showed that 0.25 and 0.40 had low likelihoods) with a linear relationship from age 1 to age 4. These values will form part of the new grid. The estimate of M_4 was bounded within the range of M_1 and M_{10}. It was noted that the selected range might need further consideration if other elements of the model and/or grid are modified.

Effective sample size for catch at length data

28. The WG discussed the 2 options proposed and used in the grid proposed for the effective sample size to use for the multinomial (catch at age composition data). Both SQRT and Original/2 are changes to the original choices of effective sample size, and are not based on the original estimated actual sample sizes. In the case of the catch at age data the standard deviation of the normalised residuals will be examined to see any divergence from 1.0.

29. A consideration of the standard deviation of the normalised residuals for the catch at length data showed that LL2 and LL4 data appeared to be over-weighted. The effective sample size for both these datasets was reduced by one quarter to reduce the weight to an appropriate level relative to the other datasets. After reviewing diagnostics to evaluate keeping sample-size differences in the grid, the WG opted to retain the “sqrt” specification as this showed greater variability in spawning biomass without greatly affecting median trends.

Code and graphics for diagnostic analysis

30. The WG agreed on the diagnostics to evaluate goodness of fit between model runs and graphic output was developed to help the WG identify and interpret changes in the huge arrays of data and model fits (e.g., frequencies of standard deviations of normalized residuals, bubble plots of residuals for catch at age and length; examples in appendices and archived electronically).

Steepness assumptions about stock-recruitment relationship

31. With the revised catch time series and other changes, the likelihood-weighted operating model indicated that higher values of steepness were more likely compared to previous model configurations (Fig. 6, **Attachment 7**).

32. The WG agreed to retain the current steepness values for the grid as a default. In light of the results, i.e., low likelihood of low steepness, the WG recommended that analysts evaluate performance across the full range of steepness from 0.3 and 0.9 as a priority for consideration by the 2009 SC. Furthermore, the effects of

correlation between steepness and natural mortality were identified as being important and needing consideration.

2.3 Definition of changes in the structure/parameterization of the conditioning model, including new data inputs and likelihood assumptions

33. A number of changes to the OM were evaluated to determine the preferred model and grid specification.

Tagging data

34. In previous versions of the OM (up to and including sbtmod21), the 1990s tag release and recapture data had been modelled by pooling over cohorts, and not keeping track of the year of release. The SBT tagging experiments were designed so that cohorts were tagged in multiple consecutive years, and therefore the recapture data contain information on both fishing mortality and natural mortality. By pooling the data across cohorts, the information on natural mortality is reduced.

35. The most recent version of the OM (sbtmod22) includes an alternative model for the tag data, based on a Brownie model (Brownie et al. 1985). Brownie models were designed for analyzing multiyear tag data, and can provide direct estimates of both natural and fishing mortality rates. The ability of the Brownie approach to separate natural and fishing mortality rates is a direct result of the multiple release events.

36. The tag return model in sbtmod22 takes into account reporting rate estimates (the same as those used in sbtmod21), as well as tagger-specific estimates of shedding rates (CCSBT-ESC/0608/21). However, the tag model in sbtmod21 ignored tag shedding.

37. The tag model assumes complete mixing between tagged and untagged fish after the first year of release. To try to evaluate this assumption (i.e., to evaluate the degree of mixing), the WG requested an analysis of tag return rates in the Japanese LL fishery in statistical areas 7, 8 and 9. Plots of the number of tags returned per 1000 fish caught for ages 2 to 5 showed, in general, higher return rates from area 7 (see Figures in **Attachment 7**). This is suggestive of incomplete mixing, although other factors may also contribute (such as different reporting rates between areas, different levels of possible unreported catches between areas, etc.). The WG noted that if only a fraction of the overall population is available to tagging, then incomplete mixing could result in biased estimates of F (overestimates; Polacheck et al. 2002). It was requested that a robustness trial be developed that considered this possibility.

Tag Likelihood

38. In sbtmod21, the likelihood for the tag return data is based on an approximation to the Poisson distribution. If the tag recapture process is governed by a Poisson distribution, a square root transformation will produce variables that are approximately normally distributed with a standard deviation of 0.5. In practice the distribution of tag recoveries is likely over-dispersed relative to the Poisson assumption, so the actual variance, σ_T^2, used in the model fit was specified as an input to the model.

39. In sbtmod22, the likelihood for the tag return data is based on a Brownie model (see Polacheck et al. 2006. Can. J. Fish. Aquat. Sci**.** 63: 534–548). To account for over-dispersion in the tag return data relative to a multinomial distribution, the model uses a Dirichlet-multinomial distribution, parameterized such that the amount of variance in the data is φ times that of multinomial data. Full specification of the tag model can be found in Model equations in **Attachment 6**. The value of φ is specified as an input to the model. In estimation trials with sbtmod22 that assumed a multinomial distribution for the return data, the value of φ was estimated to range from 2.2 to 2.9, with an average of 2.35 over the whole grid.

Aerial survey

40. The aerial survey data have now been added to the reference set of the OM. A log-normal likelihood with autocorrelated error and added process error was used (see **Attachment 5**).

2.4 Possible changes in the structure/parameterization of the projection model

41. No changes were proposed relative to SAG/SC 2008.

2.5 Selection of a new candidate reference set, including specification of axes of uncertainty and weights to be used for constant-catch projections in 2009

42. The following table shows the specification of axes to be considered for the new "grid" based on discussions during the WG meeting:

Table 2. Specification of axes to be considered for the new "grid."

	Levels	Cumul N	Values			Prior	Simulation Weights
Steepness (*h*)	3	3	0.385	0.55	0.73	0.2, 0.6, 0.2	Prior
M_1	2	6	0.30	0.35		Uniform	Likelihood
M_{10}	3	18	0.07	0.1	0.14	Uniform	Likelihood
Omega	1	18		1		NA	NA
CPUE series	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

2.6 Selection of sensitivity trials

43. The WG reviewed the sensitivity trials suggested at previous SAG meetings and agreed that the following be pursued for the full grid:

- Effects of overcatch on *CPUE*: S = 0%, 50% and 75%.
- *LL1* overcatch scenario based on Case 2 of Market Report.
- Projected recruitment deviates uncorrelated to historical estimates from conditioning
- Include troll survey data
- Truncate *CPUE* series in 1992
- Substitute alternative CPUE series 3 and 6 (see **Attachment 5**)
- Break *CPUE* into two time series, the second starting in 1986

- Use likelihood-based weights for M_1, and M_{10} for grid integration (retain estimation of M_4 and M_{30})
- Omega value of 0.75 (CPUE non-linearity factor)
- Increase the CV on *CPUE* to 0.30
- For modelling the tagging data component: investigate a range of proportional increases in the season-1 *F*'s (*H*) (during which the surface fishery occurs) in the tagging likelihood as a first approximation to address the effect of incomplete mixing. (See **Attachment 6**).

Agenda Item 3. Constant-catch projections

3.1 TAC options and allocations

44. The SFMWG had requested results for five alternative future constant catch projections: 1) TAC in 2009, 2) TAC 2009 + 2000 t, 3) TAC 2009 - 2000 t, 4) TAC 2009 + 4000 t, and 5) TAC 2009 - 4000 t. The year in which TAC would change for future catch projections is 2010. The SC was also asked to produce a projection based on zero catches as a baseline against which to assess other catch projections and the biological capacity of the stock.

45. The reference points to be reported from constant catch projections were suggested to include:

- probability of B2014 > B2004,
- probability of B2014 > B2008,
- medians and lower 10th percentiles of B2014/B2004, B2014/B2008, B2022/B2004, B2022/B2008,
- medians of B2008/B1980, B2008/B0, where B is spawning biomass.

46. For the SC, the group recommended that B2009 replace B2008 for the figures detailed above.

47. Projections will be based on the following allocations by fishery:

LL1 = 0.3963

LL2 = 0.0960

Indonesia = 0.0639

Surface = 0.4439

48. These allocations were based on allocations in t by country as follows: Japan 3000, Australia 5265, Korea 1140, Taiwan 1140, NZ 420, Indonesia 750, Philippines 45, SA 40, EC 10.

3.2 Time horizon for simulations

49. The group agreed to use 20 years for projections

3.3 Performance statistics, tables and graphics

50. The SFMWG has requested that the SC provide advice on the consequence of future catch levels in the form of that provided in Table 2 of the report of the Eleventh Meeting of the SC, but with the addition of a 30th percentile and inclusion of spawning biomass performance statistics for B_{2020}/B_{2010} and

B_{2025}/B_{2010}. The SC was also asked to determine the value of MSY in 2009 if possible (otherwise by 2010). It was requested that the Secretariat prepare a figure that shows the relationship between the current stock status and target reference points identified by the Commission. In addition to this table, the SFMWG requested that the ESC also provide graphs of the projection outcomes. The group noted that for the current allocation, the selectivity affects estimates of F_{msy}. These are presently being calculated and will be provided in the future.

Agenda Item 4. Future MP work

51. The group deferred discussion of this to the ESC. The MP development is expected to begin after the next ESC recognizing that this will entail a substantial commitment of resources including intersessional meetings.

Agenda Item 5. Coding Issues and Workplan

5.1 Update code of OM / grid for constant-catch projections and associated graphics files

52. A considerable amount of code updating occurred during the meeting and requires further cleaning and refinements in addition to documentation prior to release. The group recommended that a code-versioning system be implemented to facilitate changes. This will be critical in particular as new people become involved. The group recommended that an example coding/documentation system be developed and presented for consideration at the 2009 ESC.
53. The group recommended that resources be devoted to coding issues, e.g., resolving redundancy, adding clarity, and ensuring transparency.
54. The group recommended that data be consolidated into one file for the new tagging data.
55. Distribution of simulation code and data/parameter sets to National Scientists
56. The code including R routines will be distributed as soon as possible,

5.2 Scientists conduct Scenario modelling

57. National scientists will be conducting the runs as they are identified.

Agenda Item 6. Close of meeting

6.1 Adoption of report

58. The WG adopted the report.

6.2 Close of meeting

59. The meeting closed at 14:15, July 17, 2009.

References

Brownie, C., Anderson, D.R., Burnham, K.P., and Robson, D.S. 1985. Statistical inference from band recovery data: a handbook. US Fish Wildl. Resour. Publ. 156.

Polacheck, T., Eveson, J.P., and Laslett, G.M. 2002. Tagging in a spatial context: design and analysis considerations. Appendix 12 of Estimation of mortality rates from tagging data for pelagic fisheries: analysis and experimental design. Final Report to the Fisheries Research and Development Corporation. FRDC Project 2002/015. ISBN 1 921061 03 0.

List of Attachments

Attachments

1 List of Participants

2 Agenda

3 List of Documents

4 Catch and CPUE scenarios

5 Report of the CPUE Working Group Meeting

6 Operating Model developed for SBT MP testing

7 Structure and conditioning of the operating model

Attachment 1

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Operating Model and Management Procedure Technical Meeting
and
CPUE Working Group Meeting

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INTERPRETER

Ms Yoko YAMAKAGE

Attachment 2

Agenda
Operating Model and Management Procedure Technical Meeting

Terms of Reference

Decide input data and final structure of operating model to be used at SC14 (September 2009) for stock assessment and constant-catch projections. This includes:

a) OM structure
- Input data for conditioning and likelihood specifications
- Overcatch and CPUE scenarios
- Axes of uncertainty (development of grid)
- Goodness of fit / diagnostics

b) Projection methods
- TAC options to be considered and performance

Agenda

1. Inputs to the Operating Model

1.1. Historical catches and size compositions.

1.2. CPUE scenarios.

1.3. Other data inputs.

2. Reconsideration of Operating Models

2.1 Review of inter-sessional analyses conducted by national scientists.

2.2 Consideration of additional estimation trials to be performed/evaluated during the meeting.

2.3. Definition of changes in the structure/parameterization of the conditioning model, including new data inputs and likelihood assumptions.

2.4 Possible changes in the structure/parameterization of the projection model.

2.5 Selection of a new candidate reference set, including specification of axes of uncertainty and weights to be used for constant-catch projections in 2009.

2.6 Selection of sensitivity trials.

3. Constant-catch projections

3.1 TAC options and allocations

3.2 Time horizon for simulations.

3.3 Performance statistics, tables and graphics

4. Future MP work

4.1 MP data inputs

4.2 Initial discussion of robustness trials for MP evaluation.

4.3 Other

5. Coding Issues and Workplan

5.1 Update code of OM / grid for constant-catch projections and associated graphics files.

5.2 Distribution of simulation code and data/parameter sets to National Scientists.

5.3 Scientists conduct Scenario modelling.

6. Close of meeting

6.1 Adoption of report

6.2 Close of meeting

Attachment 3

List of Documents and Working Papers
Operating Model and Management Procedure Technical Meeting (OMMP)
and
CPUE Working Group Meeting (CPUE)

Documents (CCSBT-OMMP/0907/)

1. Draft Agenda
2. Draft List of Participants
3. Draft List of Documents
4. (Australia) Exploration of the Southern Bluefin Tuna operating model and constant catch projections, 2009. Giannini, F., Barnes, B., Begg, G., Davies, C.
5. (Japan) Further examinations of the SBT operating model to explore new tagging model and grid specifications. Hiroyuki Kurota, Osamu Sakai, Norio Takahashi and Doug S Butterworth.

Working Papers (CCSBT-CPUE/0907/WP)

1. (Japan) Correction factor for RTMP based CPUE (May 2009). Tomoyuki Itoh.
2. (Australia) Examining concentration patterns of SBT CPUE (February 2009). Fiona Giannini.
3. (Japan) Preliminary analysis on standardized CPUE for each quartile length group (July 2009). Tomoyuki Itoh.
4. (Japan) CPUE comparison between with and without observer (July 2009). Tomoyuki Itoh.
5. (Japan) Number of 5x5 and 1x1 degree square operated (May 2009). Tomoyuki Itoh.
6. (Japan) Adjusting for non-SBT targeting (May 2009). Tomoyuki Itoh.
7. (Australia) Including effort as an offset in CPUE standardisation of SBT (February 2009). Chris Drovandi.
8. (CPUE Chair) An investigation into the basis for using the %Zeros term to correct for by-catch effort in SBT CPUE time series and into other possible by-catch correctors (February 2009). John G. Pope.
9. (Australia) Including vessel random effects in CPUE standardization (February 2009). Chris Drovandi.
10. (Japan) Including fixed vessel effect in CPUE standardization and comparison by two data sets between 5x5 and shot-by-shot (May 2009). Tomoyuki Itoh.
11. (Australia) Accounting for zero shots in the CPUE standardisation of SBT (May 2009). Chris Drovandi.

12. (Japan) Making the new dataset and different core vessels definition (February 2009). Tomoyuki Itoh and Osamu Sakai.

(CCSBT--OMMP/0907/Rep) (CCSBT--CPUE/0907/Rep)

1. Report of the Special Meeting of the Commission (July 2006)
2. Report of the Seventh Meeting of the Stock Assessment Group (September 2006)
3. Report of the Eleventh Meeting of the Scientific Committee (September 2006)
4. Report of the Thirteenth Annual Meeting of the Commission (October 2006)
5. Report of the Eighth Meeting of the Stock Assessment Group (September 2007)
6. Report of the Twelfth Meeting of the Scientific Committee (September 2007)
7. Report of the Ninth Meeting of the Stock Assessment Group and Fifth Meeting of the Management Procedure Workshop (September 2008)
8. Report of the Thirteenth Meeting of the Scientific Committee (September 2008)
9. Report of the Fifteenth Annual Meeting of the Commission (October 2008)
10. Report of the Strategy and Fisheries Management Working Group Meeting (April 2009)

Attachment 4

Catch and CPUE scenarios

Ana Parma – 31 May 2009

Note: The spreadsheet scenarios2009.xls included with the conditioning code (worksheet "multipliers") computes the adjustment factors from the data in SEC_ManagementProcedureData_52_08.xls and from estimates of unreported catch. The grey shaded area was pasted into sbtdata2008.dat).

The table below summarizes the catch and CPUE scenarios selected at SAG9. They differ in the size of the unreported catch (UC) assumed for LL1, and on the extent of the effect of UC on CPUE:

		Scenarios from SAG9		
		a (base)	b	c
CPUE	Effect of unreported catch on CPUE	25%	50%	75%
Surface fishery	Farm age composition	shifted for 20% increase in average weight		
LL1	Assumed lag from *LL1* catch to fish appearing in market	$\hat{M}_y = 0.07C_{y-1} + 0.86C_{y-2} + 0.07C_{y-3}$		
	LL1 unreported catch in 2005	assumed equal to 2004		
	Market estimates	Case 1 from Market Report as base and Case 2 as sensitivity		
	Overcatch prior to 1989	Assumed to be zero for Case 1; for Case 2 it is positive in some years since 1983		

1) **Surface catch**

Total catches in numbers are assumed correct. Age composition is shifted to increase average weight in the farm catch by 20% (as in scenario S2* developed at SAG7 in 2006).

The original proportions and mean weights at age used were:

	1	2	3	4	5	6	7	8
1992	0.050874	0.261420	0.606122	0.080643	0.000937	0.000001	0.000000	0.000005
1993	0.000275	0.261698	0.624148	0.104761	0.008816	0.000282	0.000000	0.000021
1994	0.000027	0.009560	0.727660	0.245850	0.015437	0.001238	0.000228	0.000000
1995	0.002544	0.142437	0.701724	0.137220	0.014985	0.001089	0.000000	0.000000
1996	0.000000	0.093958	0.692645	0.205707	0.007549	0.000141	0.000000	0.000000
1997	0.007306	0.111984	0.674456	0.167153	0.037167	0.001860	0.000075	0.000000
1998	0.000000	0.131801	0.727755	0.133085	0.007136	0.000218	0.000005	0.000000
1999	0.000000	0.095114	0.851860	0.043330	0.009696	0.000000	0.000000	0.000000
2000	0.000000	0.117410	0.687546	0.183272	0.010949	0.000822	0.000000	0.000000
2001	0.000000	0.102982	0.783528	0.091725	0.018144	0.003621	0.000000	0.000000
2002	0.000000	0.066348	0.822416	0.094977	0.012889	0.002471	0.000899	0.000000
2003	0.000495	0.153449	0.635024	0.193301	0.013837	0.003013	0.000882	0.000000
2004	0.000000	0.307592	0.647391	0.043227	0.000979	0.000000	0.000181	0.000629
2005	0.054621	0.501829	0.370091	0.067469	0.003596	0.001959	0.000436	0.000000
2006	0.047044	0.380088	0.555437	0.014625	0.002805	0.000000	0.000000	0.000000

2007	0.000394	0.092607	0.431217	0.440212	0.031776	0.003795	0.000000	0.000000
2008	0.000000	0.021689	0.303543	0.628034	0.043911	0.002337	0.000486	0.000000
Weights:	0.009757	0.017976	0.026579	0.035517	0.044366	0.0528419	0.060771	0.003295

The redistribution of numbers-at-age caught was expressed as follows:

$$N'_{t,2} = (1 - p_t)\,N_{t,2}$$

$$N'_{t,3} = (1 - p_t)\left(p_t N_{t,2} + N_{t,3}\right)$$

$$N'_{t,4} = N_{t,4} + p_t\left(p_t N_{t,2} + N_{t,3}\right)$$

where $N_{t,2}, N_{t,3}, N_{t,4}$ are the original numbers at age in year *t*, and p_t is a redistribution parameter for shifting age 2 and 3 year-old SBT. The values of p_t were estimated to meet the constraint that the resulting farm catch weight was 20% higher than the reported values. The actual parameter values and resulting proportions at age are shown in Table 1.

Table 1. Values of p_t and proportions at age for SBT in the surface fishery to produce a 20% overcatch in weight.

	p_t	1	2	3	4	5	6	7	8
1992	0.0213	0.0509	0.2558	0.5987	0.0937	0.0009	0.0000	0.0000	0.0000
1993	0.2112	0.0003	0.2064	0.5359	0.2482	0.0088	0.0003	0.0000	0.0000
1994	0.4146	0.0000	0.0056	0.4283	0.5492	0.0154	0.0012	0.0002	0.0000
1995	0.3803	0.0025	0.0883	0.4684	0.4247	0.0150	0.0011	0.0000	0.0000
1996	0.4061	0.0000	0.0558	0.4340	0.5025	0.0075	0.0001	0.0000	0.0000
1997	0.2468	0.0073	0.0843	0.5288	0.3405	0.0372	0.0019	0.0001	0.0000
1998	0.3742	0.0000	0.0825	0.4863	0.4239	0.0071	0.0002	0.0000	0.0000
1999	0.4196	0.0000	0.0552	0.5175	0.4176	0.0097	0.0000	0.0000	0.0000
2000	0.5086	0.0000	0.0577	0.3672	0.5633	0.0109	0.0008	0.0000	0.0000
2001	0.4587	0.0000	0.0557	0.4497	0.4728	0.0181	0.0036	0.0000	0.0000
2002	0.4708	0.0000	0.0351	0.4518	0.4969	0.0129	0.0025	0.0009	0.0000
2003	0.5065	0.0005	0.0757	0.3517	0.5543	0.0138	0.0030	0.0009	0.0000
2004	0.3516	0.0000	0.1994	0.4899	0.3089	0.0010	0.0000	0.0002	0.0006
2005	0.3172	0.0546	0.3427	0.3614	0.2353	0.0036	0.0020	0.0004	0.0000
2006	0.3204	0.0470	0.2582	0.4602	0.2316	0.0028	0.0000	0.0000	0.0000
2007	0.3154	0.0926	0.2952	0.3945	0.2135	0.0038	0.0000	0.0000	0.0000
2008	0.3536	0.0217	0.1962	0.4754	0.3039	0.0023	0.0005	0.0000	0.0000

2) Scenario for LL1 UC

The SAG9 supported the use of information in paper CCSBT-ESC/0809/40 to recalculate the market anomalies and corresponding *LL1* unreported catch scenarios. Caveats related to the inappropriateness of applying information collected in 2007-2008 to previous years given many changes in the fishery were acknowledged, but the information was still considered better than that used to justify the previous (0.30-0.70) assumption. A new scenario for unreported *LL1* catches was produced by solving for the catches that minimized the differences between the market estimates M_y for each year *y* and the expected overall market volume $\hat{M}_y$ predicted from the lagged catches C_y according to

$$\hat{M}_y = 0.07C_{y-1} + 0.86C_{y-2} + 0.07C_{y-3} \qquad (1)$$

where C_y are the total $LL1$ catches (reported + UC). The M_y were set at the Case 1 market estimates for 1985-2005 (by Lou and Hidaka, pages 97-98 of Market report), same as used to compute scenarios "b", "c" and "d" at SAG7. Also, the UC for 2005 was set equal to the UC of 2004. The "Solver" tool of Excel was used to minimize the sum of squared differences between M_y and $\hat{M}_y$.

Prior to 1990 the market anomalies (i.e., the difference between the market estimates and those predicted from lagged reported catches) were small on average and some were negative (Figure 1). The sum of the calculated UC_y prior to 1989 was small (less than 250 mt). Considering the uncertainties in the market estimates and the small cumulative UC estimated over this period, the SAG decided to maintain the assumption of zero UC prior to 1989 made by SAG7.

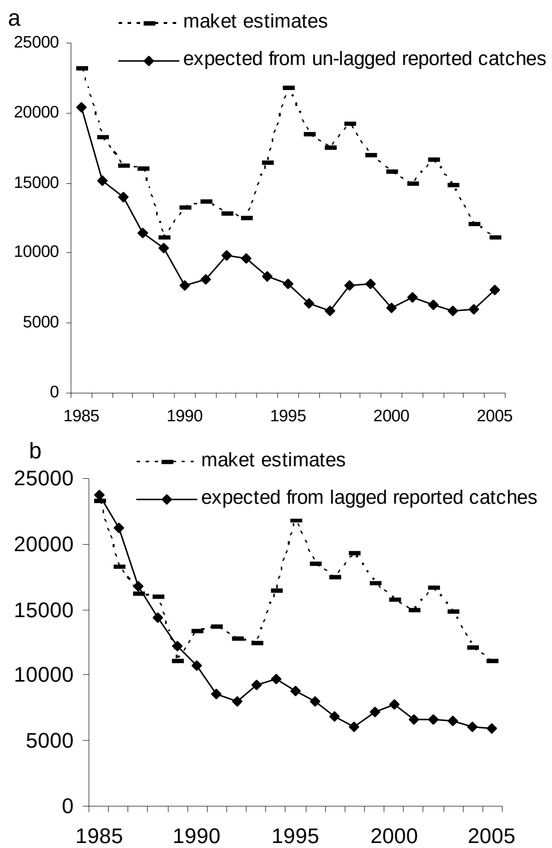
Market estimates provided by Bergen and Kageyama (Case 2) will be used to conduct a sensitivity test.

Cases kept in data file:

Case L0 : Zero effect, kept for reference.

Case L1 (old L4): Market anomalies re-estimated by lagging the catches using equation (1) and market estimates by Lou and Hidaka for 1985-2005; UC(2005) set equal to UC(2004).

Case L2: same as L1 but market estimates based on Case 2 of Market report.



The UC was allocated all to LL1.

3) Impacts on CPUE

The derivations below detail some of the complications involved in calculating the impact of the *LL*1 UC on the CPUE series. These are related to how the UC is allocated among subfleets and what fraction of the effort associated with the UC is reported (hereon called *S*). The three main options here called C1, C2, C3 are:

Case C0: *S*= 0.
Case C1: *S*=0.25, Option A
Case C2: *S*=0.5, Option A
Case C3: *S*=0.75, Option A

Let $\%LL1$ be the unreported catch in *LL*1 (UC_{LL1}) expressed as a percentage of the nominal catch C_{LL1}

$$\%LL1 = \frac{UC_{LL1}}{C_{LL1}} 100$$

Note that the adjusted *LL*1 catch used in conditioning will be:

$$\text{adj}C_{LL1} = C_{LL1}\,(1 + \%LL1/100)$$

There are a number of alternatives to go from $\%LL1$ to a CPUE adjustment, depending on how much of UC_{LL1} affects the Japanese *LL*1, and how much of it corresponds to the reported effort. A simple alternative would be to define the scenario in terms of a factor (*x*) and compute the CPUE adjustment as

$$\text{CPUE adjustment} = 1 + x\ \%LL_1/100\,. \tag{1}$$

In this case *x*=1 would mean that the same adjustment applied to the catch is used for CPUE. This approach ignores the fact that only a portion of *LL*1 goes into CPUE computations and a part (albeit small) of the CPUE comes from NZ chartered and Australian joint venture (assumed to have zero UC because of 100% observer coverage). The difference made by these factors was evaluated using the historical fractions of *LL*1 catch by subfleet provided by the Secretariat.

To obtain the CPUE correction, first define $\%LL1_J$ as the relative adjustment that would apply to the Japanese catch used for CPUE computations

$$\%LL1_J = \frac{UC_{LL1_J}}{C_{LL1_J}} 100$$

The scenarios selected at the SAG 2006 were constructed assuming that UC_{LL1} is distributed amongst *LL*1 subfleets, areas and months in proportion to the nominal catch, except for the Australian joint venture and New Zealand charter fleets (called Option A). The alternative (Option B) is to attribute all the UC to the Japanese catch. Under the proportionality assumption,

$$\%LL1_J = \frac{UC_{LL1_J}}{C_{LL1_J}} 100 = \frac{UC_{LL1}}{C_{LL1} - C_{LL1_{NZ}} - C_{LL1_{Aus\ JV}}} 100$$

where $C_{LL1_{\text{NZ}}}$ and $C_{LL1_{\text{Aus JV}}}$ are the catches of the Australian joint venture and New Zealand charter fleets. Because these two subfleets have a small share of C_{LL1}, the Japanese adjustment will be similar to the overall *LL*1 adjustment under this option.

Once $\%LL1_J$ is calculated, assume that a fraction S of it was caught with the effort reported. Then the multiplier to CPUE would be:

$$\text{CPUE adjustment to Japanese portion} = 1 + \text{S } \%LL1_J / 100$$

and

$$\text{CPUE adjustment} = (1-P) + P\,(\text{CPUE adjustment to Japanese portion})$$

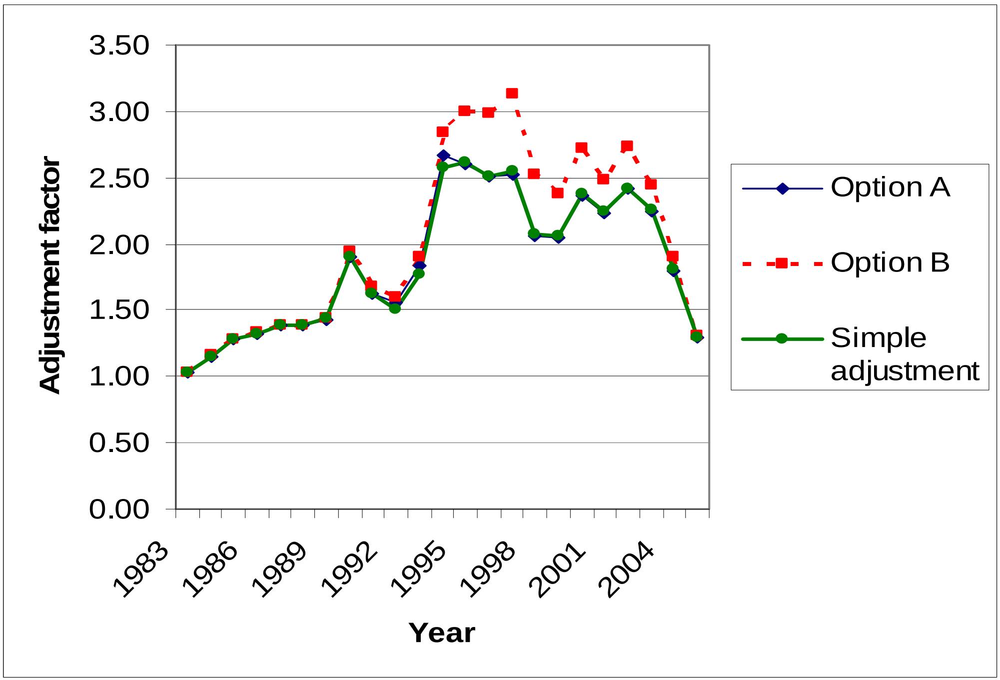
where P is the fraction of the CPUE catch that is Japanese. Combining the previous,

$$\text{CPUE adjustment} = 1 + P \text{ S } \%LL1_J \quad / 100$$

Or, expressed as a function of the relative catch adjustment,

$$\text{CPUE adjustment} = 1 + \frac{P\,S}{\text{fraction of } C_{LL1} \text{ affected}} \%LL1/100 \qquad (2)$$

In the end, all these fractions are multiplied together to define the factor x in equation (1), where S contributes the largest uncertainty. Because P and $\%LL1_J$ are known, they may provide some upper bounds on the multipliers to CPUE. Depending on the values of P and the fraction of C_{LL1} affected by unreporting the CPUE adjustments may be larger or smaller than the multipliers applied to C_{LL1} even if S is set to 1 (100% reported effort). The figure below shows the difference between the simple approach (green solid line) and options A (blue solid) and B (red dotted) when S=1 and the scenario of largest UC_{LL}, allocated all to $LL1$ is chosen.



Option A and the simple adjustment are practically the same. The only difference is that the simple adjustment ignores the fact that there is a small contribution of NZ chartered and Aus JV (P<1) in the CPUE and that these fleets are also in $LL1$. The largest difference between the alternatives is due to how the UC is allocated among $LL1$ subfleets (Option A versus Option B). To get the maximum effect (as obtained with Option B when all the UC is allocated to $LL1$ Japanese and it is assumed that

100% effort has been reported) using the simple method would require $x > 1$ and the trend would not be the same.

4) Impacts on tagging reporting rates

Australia computed adjusted tagging reporting rates using the catch scenarios above under two alternative assumptions about the reporting rate of tags recovered in the UC: these tags were not reported or they were reported at the same rate as the rest. In exploratory analysis they found that conditioning results were not too sensitive to the assumption made and concluded that it would not be worthwhile to include an additional assumption for the reporting rates. The reporting rates used were computed assuming that no tags are returned from the UC.

Attachment 5

Report of the CPUE Working Group Meeting
13 to 17 July 2009, Seattle, USA
Chair: John Pope

1. Opening

The Chair explained that the group would meet in a series of sessions at such times as the concurrently running Operating Model and Management Procedure (OMMP) WG was in recess. Attendee at the meeting and the list of working papers used by the CPUE group are shown at Attachments 1 and 3 of the OMMP Report respectively. The 2009 work programme for the CPUE group is at Table 1 at the end of this attachment.

2. Agree to agenda and appoint reporters

The agenda was agreed to with the following amendments:

- Agenda item 5 and 7 merged as agenda item 5
- Addition of an item under agenda item 4: 4.4 Decide if there are any candidates for replacing the base series
- Addition of an item under agenda item 6: 6.2 Confirmation of changes made to data used for base series.

3. Specifying how to correct the RTMP estimate of CPUE in the last year of the CPUE series

Logbook data are used to fit the base CPUE model but these data are only available 2 years after the fishing operations has occurred. RTMP data are generally available a year earlier than the logbook data, and thus basing the most recent years CPUE on the RTMP data provides a more current measure of CPUE. RTMP vessels provide information on sets with positive SBT catches (even if SBT was caught as a bycatch) but, unlike logbook data, do not necessarily include fishing effort information about sets where SBT were not caught. However, CCSBT/0907/WP01 showed that RTMP vessels have reported operations without SBT catches in the same way for the last four years. If RTMP data are to be used to provide CPUE estimates for the year where they are available and the corresponding logbook data are not, an appropriate correction needs to be made to avoid bias in the last year of the CPUE series. CCSBT/0907/WP01 investigates this by calculating the ratio of nominal CPUE obtained from the RTMP data to nominal CPUE obtained from the logbook data. This is calculated for all data in areas 4-9 and for each of the areas separately. The results show the greatest ratio between RTMP and logbook data in the series for area 4. Even for this series the ratio is reasonably close to 1 after 2002. It was noted that new management practices commencing in 2006 could also effect information reported through the RTMP. It was clarified that the analysis of CCSBT/0907/WP01 was made using the whole data set. It was agreed that the analysis should be repeated using only the core vessels, to correspond to the data set used by the base CPUE model, and that using the same vessels for both the RTMP and logbook data sets will allow a more appropriate correction factor to be calculated. It was agreed that calculation of the correction factor should be done only using data after 2006 to take into account potential effects of the new management regime. The CPUE modelling WG requested their Japanese colleagues to provide corrections revised using this approach, if possible for the 2009 ESC meeting. It would be helpful to have estimates of standard deviation of these estimates. It was noted that presently RTMP based CPUE estimates are not used by the OMMP WG for retrospective analyses but that it was possible to anticipate their use in predictions.

4. Providing robustness tests for CPUE series and monitoring the future performance of the chosen series

Introductory comments on the rationale for determining how CPUE series should be chosen to be used in robustness testing or in monitoring the future performance of the base series, were made by the chair. Two main objectives were indicated:

1. to provide challenging but believable alternatives to the base CPUE series interpretation to test MPs for robustness under uncertainties in CPUE assumptions, and
2. to provide alternative CPUE series to monitor for future anomalies with the agreed series.

A presentation was made as introduction to discussions on CCSBT/0907/WP03. This paper (WP03) investigates the differences in CPUE trends when modelling data from different size groups. The data did not support the inclusion of the interaction terms included in the base model so the series used main effects only. It was clarified that this analysis was conducted on the entire data set rather than to the core vessel data set. It was suggested that there were some problems in the model fits as indicated by the Q-Q plots which suggest a different link function should be used, as well as using only the core vessels. It was agreed that this work would need to be taken further in order to be considered as a robustness or monitoring series, but that at this stage, this work was of a low priority.

There was a discussion as to the historical reasons for the w0.5 and the w0.8 weightings of the series. The differences in these series are due to different weightings of series based on the constant squares (CS) and variable squares (VS) assumptions. It was noted that the results from archival tagging studies could provide information on which assumption might be more appropriate.

A summary of papers presented at previous web meetings were discussed. It was noted that no progress had been possible on topic b2.

Paper CCSBT/0907/WP03 was presented at the February web-meeting and encouraged a follow up paper CCSBT/0907/WP05 at the May web-meeting. In relation to CCSBT/0907/WP05, it was agreed that plots of the time series of numbers of 5x5 cells fished, and 1x1 cells fished, would be useful in monitoring the base CPUE series. These plots allow investigation of whether trends in the finer scale 1x1 data are being captured in the coarser 5x5 data. These plots also provide information to evaluate the CS and VS assumptions. It is also of use in comparing trends between the core vessel set used in CPUE standardisation and the entire data set. If the CPUE based on the core vessel dataset continues to be used, similar plots should be assessed on a regular basis to ensure that the core vessel dataset is achieving the desired result and is not contradicting the trends in the dataset for all vessels. It was noted that in general, some care should be made in interpretation of the plots as fewer cells may be fished due to reduction in allocations. Currently, these plots show little difference in trend between the two different scales of data, or the core vessel and whole data set, but it was agreed that it would be useful to have these plots included in the annual ESC indicator papers if possible to monitor for future changes.

Paper CCSBT/0907/WP06, where different methods of adjusting for non-SBT targeting were investigated, had been discussed in the May web meeting. Run 6 in CCSBT/0907/WP06 was raised as being sufficiently challenging to the base series, and so was identified as a series for a possible robustness test. Run 6 models the main effects used in the base series for those operations where only SBT was caught. Of the four other series, run 3 and run 5 had similar trends to each other, though different from the base, and run 2 and run 4 had similar trends to the base. It was agreed that the models used in run 6 and run 3 (where bycatch targeting was taken into account by a categorical variable with percentage of hauls with presence of bycatch) would be used in robustness testing. It was also agreed that the model used in run 4 (where continuous variables of the percentage of hauls without bycatch tunas were included), as it had a similar trend to the base, would be used to monitor the base series into the future.
CPUE series (for both the w0.5 and w0.8 weighting) from model 3 and 6 were provided to the OMMP WG.

The equations used for the base model and models 3 and 6 were as follows.
The “Base” model is .

*“log(CPUE+0.2) = Intercept + Year + Month + Area + Lat5 + BET_CPUE + YFT_CPUE + (Month*Area) + (Year*Lat5) + (Year*Area) + Error,*

where $Error \sim N(0,\sigma^2)$, *Area* is the CCSBT statistical area, *Lat5* is latitude in five degree bands, *BET_CPUE* is the nominal CPUE of bigeye tuna and *YFT_CPUE* is the nominal CPUE of yellowfin tuna. Note that *BET_CPUE* and *YFT_CPUE* were used as continuous variables.

Run-03：. Adds % of hauls with presence of by-catch for each 5*5 cell as categorical variables to the “Base” model less the BET_CPUE - YFT_CPUE terms). Four categories for % of hauls with presence of by-catch were adopted as follows; category 1: 0%>= and <25%, category 2: 25%> and <= 50%, category 3: >50 and <= 75%, and category 4: >75% and <= 100%.

Run-06： Uses only the 5x5 month records of pure SBT operations(i.e. those without by-catch of YFT or BET). The model included only the main effects of the “Base” model as:-

“log(CPUE+0.2) = Intercept + Year + Month + Area + Lat5 + Error.

Figure 1 compares the trends of run 3 and run 6 to the base model trend using the w0.5 area weighting while figure 2 shows their trends with the w0.8 area weighting.

Figure 1

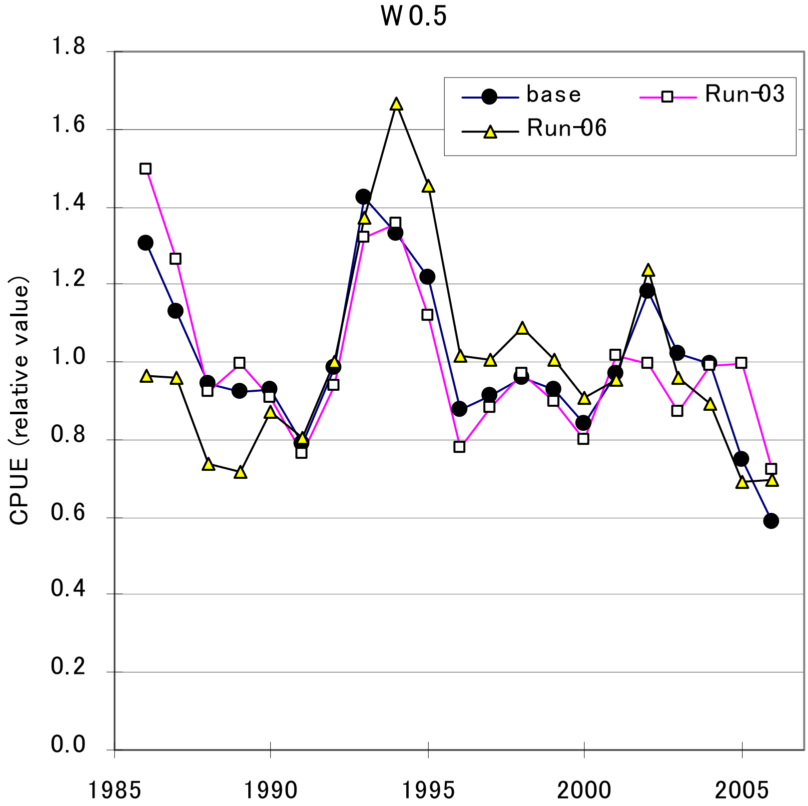
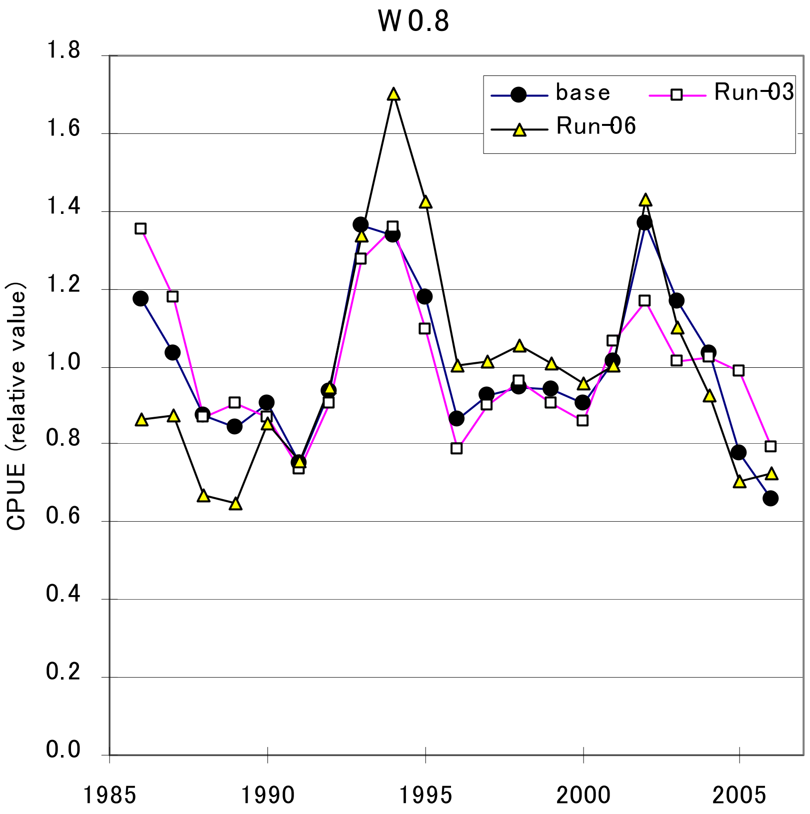

W0.5
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
CPUE (relative value)
1985
1990
1995
2000
2005
base
Run-03
Run-06

Figure 2



Paper CCSBT/0907/WP07 presented to the February 2009 web meeting showed the results of including effort as an offset in the model. The web-meeting had agreed with the author's conclusion, which was that models of this form should not be used in standardisation for the SBT data due to the poor properties in the residuals that the paper uncovered.

Paper CCSBT/0907/WP08 was presented at the February 2009 web meeting and provided the theoretical basis for the runs presented in CCSBT/0907/WP06.

The proposed GAM analysis of SBT and bycatch distributions required for task b8 in the work program could not be made by Australia as the shot by shot data for the Australian domestic longline fishery are not consistent due to seasonal spatial closures and changes in quotas. Thus this analysis would need to be made on the Japanese longline shot by shot data to be of any use. However this task work was considered to be of a low priority by the group.

Work on b9 to investigate environmental patterns of CPUE has not been done but there are data publically available for this work. These data provide oceanographic information at a fine scale which could be useful in constructing environmental explanatory variables to be included in standardisation to further explain the spatial aspects of SBT abundance. Including these data in CPUE analysis was recognised as a possible task for the future.

Paper CCSBT/0907/WP09 investigates adding vessel effects to the CPUE model. This was discussed in the web meeting in February 2009. Using YFT as a test data set the author found that out of the three models (base, including vessel as a fixed effect and including vessel as a random effect), including the vessel as a fixed effect produced the best model though currently the model produces a series that is not very different from the case. A similar analysis for SBT (CCSBT/0907/WP10 presented at the May 2009 web meeting) was made using shot by shot data for both the base model and for a model including vessel as a fixed effect. Results indicated there was little difference between model trends. It was agreed that the series with the vessel effects model should be used for monitoring in the future since the vessel effects might lead to differences in series trends from the agreed CPUE series..

In the May 2009 web meeting paper CCSBT/0907/WP11 was discussed. This paper compares different statistical approaches for accounting for zero shots in the CPUE standardisation of SBT. The author concluded that a two-stage model or the Tweedie model provided a more appropriate way of handling zeros in these data. However, the lack of means to compare the models (e.g. AIC, Q-Q plots) meant that it was difficult to provide a recommendation. The group thought the use of the Tweedie distribution, which is a flexible distribution controlled by three parameters allowing it to take many shapes (including the Normal, Poisson and Gamma distributions as special cases) with one of the parameters dealing with accommodating zeros in the data, should be further explored. It was noted that presently the model using the Tweedie distribution did not include the explanatory variables with the CPUE of the bycatch tunas as Australia does not have access to these data. It was noted that a base case model should be able to be calculated by all members.
During the discussion of this agenda item, none of the resulting series were proposed as an alternative to the standard CPUE series that the OMMP WG currently uses.

5. The effect of market anomalies on longline CPUE and possible discarding problems with longline CPUE

Paper CCSBT/0907/WP04 investigates the differences between observed sets and non-observed sets in terms of the resulting CPUE series by including an 'observer' effect and 'year*observer' interaction in the model. The paper also investigates fitting to data where SBT were 25 kg and over, in comparison to data using the usual filtering of SBT aged 4+. It was noted in a previous meeting that the higher CPUE of observed sets might be partly due to there being a higher CPUE within EEZs where observer coverage was usually high. Models were fit to data both within and outside the EEZs, and to data only outside the EEZs. The plots seemed to suggest that there was some difference between observed and non-observed sets, especially in the period 1994 to 2000. A robustness test was suggested where the base CPUE series was scaled (i.e. S) by the ratio of the indices of the series corresponding to observed sets, to the indices of the series corresponding to unobserved sets, for the period where there was substantial difference. Elsewhere the series would not be scaled. It was suggested that further work should be done to investigate whether this difference was significant before using the result in robustness testing. A possible addition to this analysis would be to use finer scale stratification of area rather than just filtering data as to whether or not they were in the EEZs. A sub-group of the WG proposed that in the first case an analysis of the core vessels data should be made that added an 'observer*year' interaction and an 'observer*EEZ' interaction to the base model.

Japanese collegues were requested to provide results of such analyses, if possible, prior to the ESC.

6. Alternative approaches to the calibration of the pre- and post-1986 CPUE and confirmation of data

The OMMP WG has calibrated the two series, pre and post 1986, through estimation in the OM, and is investigating the sensitivity to this calibration. Thus, the CPUE modelling group is not required to provide input to this process and asked the OMMP WG to make suitable calibrations.

In paper CCSBT/0907/WP12, modifications to the data set used for the CPUE series were detailed. The change is mostly attributed to discovering an error in deriving the previous data set. The new data set which for core vessels selection use years 1986 to 2006 as opposed to the years 1989 to 2005 used previously. Using the same criteria to determine which vessels should be considered "core" as used previously gives 129 core vessels in the new data set. It was thought that this may be too large for a core group so the criteria were modified to give a core data set of 100 vessels. The modified data set had been used to provide the CPUE series currently adopted by the OMMP WG and the group agreed that it should continue to be used.

7. Review future tasks for working group

a) Remaking the analysis in CCSBT/0907/WP01 using the core vessels to calculate a correction factor to be applied to the last year of CPUE if based on RTMP data.
b) Monitor the numbers of cells fished for both core vessels and all vessels at the 5x5 and 1x1 scale in the form shown in CCSBT/0907/WP05.
c) Monitoring for changes in spatial patterns of fishing since new management scheme.
d) Further analysis of differential trends in observed and non-observed trips..

8. Closure

The chair thanked the authors for the papers produced for the web-meetings and the present meeting.

Table 1: Status of CPUE Modelling Task List for 2009.

	Task	**Papers Provided and Status of task**
A	Specifying how to correct the RTMP estimate of CPUE in the last year of the CPUE series.	
a.1	Provide correction factor for RTMP based CPUE.	Paper a1.1 *(CCSBT/0907/WP01)* provided. Additional analysis proposed for SC14.
B	Providing robustness tests (RT) for CPUE series and monitoring the future performance of the chosen series.	
b.1 b.2	Size distribution Preliminary analysis for each quartile length group Clarify age-size by year and indicate analyses.).	Paper b.1 *(CCSBT/0907/WP03)* provided. Results do not yet suggest RT. Some follow up might be considered in 2010. This task could not be attempted this year.
b.3	Trends in concentration of fisheries on the fine scale Examining concentration patterns within 5x5 grids.	Paper b3.1 *(CCSBT/0907/WP02)* and b3.2 *(CCSBT/0907/WP05)* provided. Agreed to adopt results as Monitoring approach.
b.4 b.5 b.6	Adjusting for non-SBT targeting. Include abundance indices of bycatch species in CPUE model. Include measure of the Poisson excess in CPUE model. Model CPUE with fishing effort as an offset.	Complete. Paper b.4/b.5 *(CCSBT/0907/WP06)* provided. Work confirms base series and two RT series and two monitoring series. Series provided to OMMP WG. Paper b.6.1. *(CCSBT/0907/WP07)* provided. Approach dropped.
b.7 b.8	Adjusting for non-SBT targeting. Develop theory of the zero % covariate method. Propose GAM analyses of SBT and by-catch distributions	Paper b.7 *(CCSBT/0907/WP08)* provided for background to task b.5. This task could not be attempted this year and is considered a low priority for future.
b.9	CPUE patterns relative to the environment Specify and if possible supply environmental covariates.	This task could not be attempted this year. However, env. data are available for possible future work.
b.10	Vessel effects Add a vessel factor to the standard model.	Paper B.10.1 *(CCSBT/0907/WP09)* based upon YFT. And paper b10.2 (SBT) *(CCSBT/0907/WP10)* provided. Agreed as monitoring series
b.11	Zero catch adjustments. Investigate the possible use of the Tweedie distribution.	Paper b11.1 *(CCSBT/0907/WP11)* provided. Tweddie distribution considered promising approach for further work.
C	The effect of market anomalies on longline CPUE	
c.1	Make GLMs with data from observed and unobserved sets.	Paper c.1/e.1 *(CCSBT/0907/WP04)* provided. Results discussed and additional analysis proposed for SC14
D	Data Issues	
D1 D2	Alternative approaches to the calibration of the pre and post 1986 CPUE series Revision of core fleet data set	OMMP WG made runs Paper d.2 *(CCSBT/0907/WP12)* provided. Revision agreed and adjusted base series provided to OMMP WG.
E	Possible discarding/fish release problems with long-line CPUE results	
e.1	Extend studies of obs. and unobs. sets to quantify the effects of the release of small fish/discards.	Task combined with e1

Attachment 6

Operating Model developed for SBT MP testing

Conditioning model

(sbtmod22.tpl, July 2009)

Model Structure

The SBT population is modeled as a single, age-structured stock. Historical trends in growth are allowed and fixed from parameters (mean and variances at age) estimated externally. The stock-recruitment relationship is given by a Beverton-Holt function with log-normal auto-correlated errors. Six fisheries are distinguished in the conditioning analysis, occurring in two pulses, according to:

Fishery	Catch data included	Pulse (season)	Actual period used for compiling statistics
LL1	Primarily Japanese LL areas 4-9 plus all LL catches not covered in LL2-LL5	(2) 1 July	Jan 1 through Dec 31
LL2	SBT caught in Taiwanese albacore LL fishery and Taiwanese gillnet catches	(2) 1 July	Jan 1 through Dec 31
LL3	Japanese LL in Area 2	(1) 1 Jan	Jan 1 through Dec 31
LL4-size	Japanese spawning fishery (Area 1)	(1) 1 Jan	July 1 through June 30
Indonesian	Indonesian spawning	(1) 1 Jan	July 1 through June 30
Australian Surface		(1) 1 Jan	July 1 through June 30

Population Model

The model is age-structured. Fishing for each fishery is treated as a pulse that takes place in one of two fishing seasons (see Table above). The population dynamics are:

$$N_{y+1,a+1} = N_{y,a}\left(1-\sum_{f\in f^1} H_{f,y,a}\right)\left(1-\sum_{f\in f^2} H_{f,y,a}\right)\mathrm{e}^{-M_a} \quad \text{for} \quad 0 \le a \le A-2, \quad y_{n1} \le y \le y_{n2}$$

$$N_{y+1,A} = N_{y,A-1}\left(1-\sum_{f\in f^1} H_{f,y,A-1}\right)\left(1-\sum_{f\in f^2} H_{f,y,A-1}\right)\mathrm{e}^{-M_{A-1}} + N_{y,A}\left(1-\sum_{f\in f^1} H_{f,y,A}\right)\left(1-\sum_{f\in f^2} H_{f,y,A}\right)\mathrm{e}^{-M_A} \quad \text{for } y_{n1} \le y \le y_{n2}$$

$$N_{y+1,0} = R_{y+1}$$

$$N^*_{y,a} = N_{y,a}\left(1-\sum_{f\in f^1} H_{f,y,a}\right)\mathrm{e}^{-M_a/2}$$

$$H_{f,y,a} = s_{f,y,a}F_{f,y}$$

$$F_{f,y} = \frac{C_{f,y}}{\sum_a w_{f,y,a} s_{f,y,a} N_{y,a}} \quad \text{for} \quad f \in f^1$$

$$F_{f,y} = \frac{C_{f,y}}{\sum_a w_{f,y,a} s_{f,y,a} N^*_{y,a}} \quad \text{for} \quad f \in f^2$$

where: $N_{y,a}$ is the number of fish of age *a* at the start of year *y*,

$N^*_{y,a}$ is the number of fish of age *a* at mid-year *y*,

M_a denotes the natural mortality rate on fish of age *a*,

$C_{f,y}$ is the catch of fish (biomass) in fishery *f* in year *y*,

$F_{f,y}$ is the age-averaged fishing proportion of fishery *f* in year *y*,

$H_{f,y,a}$ is the fishing proportion of fishery *f* in year *y* for fish of age *a,*

$s_{f,y,a}$ is the standardized selectivity of fish of age *a* in fishery *f* in year *y,*

$w_{f,y,a}$ is the average weight of fish of age *a* in year *y* in fishery *f*,

R_y is the age-0 recruitment in year *y,*

f^1 is the set of fisheries that occur in the first season (I33),

f^2 is the set of fisheries that occur in the second season (I33), and

A is the maximum age considered (I6, taken to be a plus-group).

y_{n1}, y_{n2} are the first (I1) and the last (I2) years for the stock reconstruction.

Note that solutions are constrained so that the maximum harvest rate on an age-class during a fishing season is 0.9. For the MP reference case the maximum age considered, *A*, is 30.

Stock-Recruitment

The number of recruits at the start of year *y* (R_y) is related to the spawning stock size by a stochastic Beverton-Holt stock-recruitment relationship. The relationship includes a parameter that allows for depensatory effects and has the option for serial correlation (AC) in a terminal sub-set of the residuals:

$$R_y = \frac{\alpha^r S_y}{\beta^r + S_y} \exp(\tau_y - 0.5\sigma_R^2)\left(1 - \exp\left(\frac{\ln(0.5) S_y}{\nu B_0^r}\right)\right)$$

$$\tau_y = \begin{cases} \delta_y & \text{if no AC} \\ \delta_y & \text{if AC and } y < y_{AC} \\ \varpi \tau_{y-1} + \delta_y & \text{if AC and } y \ge y_{AC} \end{cases}$$

where S_y is the spawning stock biomass in year *y*,

α^r, β^r are Beverton-Holt stock-recruitment parameters for regime *r*,

τ_y is the stock-recruitment residual for year *y*, $\tau_y \sim N(0, \sigma_R^2)$,

ν is a depensation parameter (I23), (Note that setting ν at a very small number corresponds in the limit to no depensation),

B_o^r is the equilibrium spawning stock biomass expected during regime *r* in the absence of fishing,

δ_y	are stock-recruitment residual parameters estimated in the fitting procedure for years $y_{n1} > y \le y_{n2} + 1$
ϖ	is the empirical autocorrelation in the recruitment residuals, $\omega = Cor(\tau_y, \tau_{y-1})$, for $1966 \le y \le (y_{AC} - 4)$
y_{AC}	is the year initiating the serial correlation in the stock-recruitment residuals (must be 1996 or later to activate this option, I13).

Spawning stock biomass is estimated as:

$$S_y \sum_{a=1}^{A} m_a \left(w_{y,a}^s\right)^{\kappa} N_{y,a}$$

where m_a is the proportion of fish of age a that are mature, w_{ya}^s, the spawning weight at age a in year y is assumed to be the same as the mean weight-at-age for the Indonesian spawning fishery, and κ is the exponent for a non-linear relationship between body size and reproductive potential (I24). Note that all these parameters, m_a, w_{ya}^s, and κ are specified as model inputs.

In order to work with parameters that are more meaningful biologically, the stock-recruitment relationship is reparameterized in terms of the equilibrium spawning biomass expected in the absence of fishing, B_0^r, and the “steepness”, h, of the stock-recruitment relationship (steepness is defined as the fraction of the average spawning biomass expected in the unfished stock, which is obtained when recruitment is 20% of the recruitment expected in the unfished stock):

$$\alpha^r = \frac{4hR_0^r}{5h-1} \quad \text{and} \quad \beta^r = \frac{B_0^r(1-h)}{5h-1}$$

where

$$R_0^r = \frac{B_0^r}{\sum_{a=1}^{A-1} m_a \left(w_{y_{n1},a}^s\right)^{\kappa} \exp\left(-\sum_{a'=0}^{a'=a-1} M_{a'}\right) + m_A \left(w_{y_{n1},A}^s\right)^{\kappa} \dfrac{\exp\left(-\sum_{a'=0}^{a'=A-1} M_{a'}\right)}{1-\exp(-M_A)}}$$

Only a very limited regime shift option is currently coded in the SBT conditioning model. When the regime shift option (called carrying capacity) is invoked (I8b), an alternate stock-recruitment relationship, based on a different B_0^r, is used from 1978 onward. The two regimes share a common steepness parameter.

Selectivities

The parameterization of selectivity is age-specific and the model structure allows the selectivity to change slowly over time. For the first year in which there is catch data (I3) ($y = y_{c1}$), selectivities are functions of the estimated parameters:

$$s'_{f,y_{c1},a} = \begin{cases} 0 & \text{for } a < a_f^{mins} \\ \exp(\lambda_{f,a}) & \text{for } a_f^{mins} \le a \le a_f^{maxs} \\ \exp(\lambda_{f,a_f^{maxs}}) & \text{for } a > a_f^{maxs} \text{ and } f \in z \\ 0 & \text{for } a > a_f^{maxs} \text{ and } f \notin z \end{cases}$$

where a_f^{mins} and a_f^{maxs} are the minimum (I34) and maximum (I35) age-classes for which selectivity parameters are estimated for fishery *f*, z is the set of fisheries for which age-classes greater than a_f^{maxs} have the same selectivity as age-class a_f^{maxs} (I36). The code has two options for normalizing selectivities, controlled by a parameter hardwired in the code. The default option normalizes selectivities with respect to a reference age

$$a_f^{med} = \text{int}\left(\frac{a_f^{mins} + a_f^{maxs}}{2}\right) + 1$$

by

$s_{f,y_{c1},a} = \dfrac{s'_{f,y_{c1},a}}{s'_{f,y_{c1},a_f^{med}}}$ and forcing $\lambda_{f,a_f^{med}}$ to 0 using a quadratic penalty.

In the alternative parameterization (set jim_select = 1 in tpl code), selectivities are normalized with respect to the mean over the age range $a_f^{mins} \le a \le a_f^{maxs}$, and a quadratic penalty is added to the log of the mean selectivity for the first year to force the mean selectivity to 1. Also, in this version, when age-specific harvest rates exceed 0.90 during the minimization (i.e. “kludge” message) only the harvest rate where the bound is exceeded is reduced. In previous versions, all harvest rates were adjusted. This is a preferable way to constrain harvest rates but it is ~30% slower to run.

For other years ($y > y_{c1}$),

$$s'_{f,y,a} = \begin{cases} s_{f,y-1,a}\exp(\gamma_{f,y,a}) & \text{for } y \in c^f, \quad \gamma_{f,y,a} \sim N(0, \sigma^2_{s_y^f}) \\ s_{f,y-1,a} & \text{for } y \notin c^f \end{cases}$$

where c^f is the set of years in which the fishing selectivity ogive can change for fishery *f* (non-zero I40), and γ_{fya} reflects the amount of change in the age effect of fishery *f* for age *a*.

After each update, selectivities are again normalized according to the parameterization chosen:

$$s_{f,y,a} = \frac{s'_{f,y,a}}{s'_{f,y,a_f^{med}}} \qquad \text{or} \qquad s_{f,y,a} = \frac{s'_{f,y,a}}{\text{mean}(s'_{f,y,a_f^{mins}}, \cdots, s'_{f,y,a_f^{maxs}})}.$$

The stochastic error terms, $\gamma_{f,y,a}$ are treated as free parameters subject to the constraints of their input variances, $\sigma^2_{S_y^f}$ (I40).

If the age effects of fishing ($s_{f,y,a}$) are constant over time, this results in a decomposition of the fleet-specific fishing mortality rate into an age component and a year component. This assumption creates what is known as a separable model. If the age effect of fishing in fact changes over time, then the separable model can mask important changes in fish abundance. The constraints imposed through the variance terms can restrict the selectivity to change only slowly over time, thus improving the ability to estimate the $\gamma_{f,y,a}$'s. Also, to provide smoothness in the age component there is a curvature penalty on the age-specific coefficients. This can be based on either the logarithm of the selectivity parameters (I38=0), or a non-negative power of the selectivity parameters (I38>0):

$$x_{f,y,a} = \begin{cases} \ln(s_{f,y,a}) & \text{for I38} = 0 \\ (s_{f,y,a})^{\text{I38}} & \text{for I38} > 0 \end{cases}$$

Then a penalty term, based on either squared second-differences or squared third-differences, is added to the negative log-likelihood function for each fishery:

$$g^f\left(x_{fya};\sigma^2_{b^f}\right)=\begin{cases}\displaystyle\sum_{y\in\left(y_{c1},c^f\right)}\sum_{a=a_f^{mins}}^{a=a_f^{maxs}-2}\frac{\left(x_{f,y,a+2}-2x_{f,y,a+1}+x_{fya}\right)^2}{2\sigma^2_{b^f}} & \text{for I39 = 2}\\ \displaystyle\sum_{y\in\left(y_{c1},c^f\right)}\sum_{a=a_f^{mins}}^{a=a_f^{maxs}-3}\frac{\left(x_{f,y,a+3}-3x_{f,y,a+2}+3x_{f,y,a+1}-x_{fya}\right)^2}{2\sigma^2_{b^f}} & \text{for I39 = 3}\end{cases}$$

This prevents irregular shifts between adjacent age classes. A selection of the third differences penalty function encourages selectivity to be dome-shaped with age while the second difference penalty function favours linear behaviour with age.

Growth

Growth is not estimated in the model, but is fixed with assumed known length-age relationships. The mean length at age is input for each year y and season t, so growth can change over time. Also, fixed length-weight relationships are assumed for each fishery. The length frequency distributions for each age are calculated assuming normal distributions. The standard deviation ($\sigma_{t,y,a}$) of length-at-age is linearly related to the mean length-at-age ($\mu_{t,y,a}$) based on the relationship of Kolody and Polacheck (2001): $\sigma_{t,y,a}=2+\mu_{t,y,a}/30$.

Natural Mortality

Natural mortality is assumed to vary over age as a function of four parameters: m^1, m^4, m^{10} and m^{30}, which correspond respectively to the instantaneous rate of natural mortality at ages 1, 4, 10, and 30+.

$$M_a=\begin{cases} m^1 & \text{for } a=0\\ m^1+\dfrac{m^4-m^1}{3}(a-1) & \text{for } 1\le a<4\\ m^4+\dfrac{m^{10}-m^4}{6}(a-4) & \text{for } 4\le a\le 10\\ m^{10} & \text{for } 10\le a\le 25\\ M_{25}+\dfrac{m^{30}-M_{25}}{5}(a-25) & \text{for } 25<a<30\\ m^{30} & \text{for } a\ge 30\end{cases}$$

Two of the parameters (m^1 and m^{10}) are fixed while the other two (m^4 and m^{30}) are estimated. The parameter m^4 is bounded between $m^1$and m^{10}. Conditioning trials showed that the estimates of m^4 and m^{30} had low coefficients of variation, while there was considerable uncertainty around m^1 and m^{10}. Thus, a range of values are selected for m^1 and m^{10} to reflect that uncertainty in model projections.

Tagging Model

The tag return data are modelled using a Brownie model to take advantage of the information provided by tagging the same cohort in multiple consecutive years. By comparing the return rates over time from a cohort tagged in consecutive years, Brownie models are able to provide estimates not only of fishing mortality but also natural mortality.

The dynamics for fish that are tagged and released are assumed to be the same as those for the general population. Thus, the tagging model assumes two seasons per year, one from Jan 1 to Jun 30 and the other from Jul 1 to Dec 31, with pulse fisheries operating at the start of each season. Tag releases have generally occurred near the beginning of the calendar year, so they are treated as discrete annual events occurring at the start of the first fishing season (i.e., on Jan 1). Because newly tagged fish will not be completely mixed during the season following their release, the model allows for the harvest rate to differ between tagged fish in the season directly following their release and untagged fish in that same season.

We know that a significant proportion of tags recaptured in the fisheries are not returned. Thus, age and year-specific reporting rate estimates (based on limited observer data and a number of alternative assumptions) are included in the model. Tag shedding is another issue that needs to be taken into account. All fish were double tagged so that shedding rates could be estimated (based on the number of recaptured fish with one tag versus two tags still attached). We assume that the probability of a tag being retained after time τ (in years) at liberty can be described by

$$Q(\tau) = \xi e^{-\Omega\tau}$$

where ξ is the fraction of tags immediately retained (i.e., proportion $1-\xi$ are immediately shed) and Ω is the continuous shedding rate. Shedding rates were found to be tagger-dependent, so separate values of ξ and Ω were estimated for 6 groups of taggers found to have statistically similar shedding rates.

Taking into account all of the above, the probability of a fish from cohort *c* tagged at age *a* by a tagger in group *g* being recaptured at age *i* and having *at least one* of its two tags returned is:

$$p_{c,a,g,i} = \begin{cases} 0 & i < a \\ \left(2\xi_g f'^{*}_{c,g,i} - \xi_g f''^{*}_{c,g,i}\right)\upsilon_{c,i} & i = a \\ \left(2\xi_g S'^{*}_{c,g,a} f'_{c,g,i} - \xi_g^2 S''^{*}_{c,g,a} f''_{c,g,i}\right)\upsilon_{c,i} & i = a+1 \\ \left(2\xi_g S'^{*}_{c,g,a}\left(\prod_{j=a+1}^{i-1} S'_{c,g,j}\right) f'_{c,g,i} - \xi_g^2 S''^{*}_{c,g,a}\left(\prod_{j=a+1}^{i-1} S''_{c,g,j}\right) f''_{c,g,i}\right)\upsilon_{c,i} & i > a+1 \end{cases}$$

where

$$S'_{c,g,i} = \left(1-h_{1,c,i}\right)\left(1-h_{2,c,i}\right)\exp\left(-M_i - \Omega_g\right)$$

$$S''_{c,g,i} = \left(1-h_{1,c,i}\right)\left(1-h_{2,c,i}\right)\exp\left(-M_i - 2\Omega_g\right)$$

$$f'_{c,g.i} = h_{1,c,i} + \left(1-h_{1,c,i}\right)\exp\left(-0.5\left(M_i + \Omega_g\right)\right)h_{2,c,i}$$

$$f''_{c,g,i} = h_{1,c,i} + \left(1-h_{1,c,i}\right)\exp\left(-0.5\left(M_i + 2\Omega_g\right)\right)h_{2,c,i}$$

$$S'^{*}_{c,g,i} = \left(1-h^{*}_{1,c,i}\right)\left(1-h_{2,c,i}\right)\exp\left(-M_i - \Omega_g\right)$$

$$S''^{*}_{c,g,i} = \left(1-h^{*}_{1,c,i}\right)\left(1-h_{2,c,i}\right)\exp\left(-M_i - 2\Omega_g\right)$$

$$f'^{*}_{c,g,i} = h^{*}_{1,c,i} + \left(1-h^{*}_{1,c,i}\right)\exp\left(-0.5\left(M_i + \Omega_g\right)\right)h_{2,c,i}$$

$$f''^{*}_{c,g,i} = h^{*}_{1,c,i} + \left(1-h^{*}_{1,c,i}\right)\exp\left(-0.5\left(M_i + 2\Omega_g\right)\right)h_{2,c,i}$$

Parameters are defined as follows:

M_i	is the natural mortality rate for age *i* fish
$h_{1,c,i}$	is the proportion of age *i* fish from cohort *c* harvested in season 1
$h_{2,c,i}$	is the proportion of age *i* fish from cohort *c* harvested in season 2
$h^*_{1.c.i}$	is the proportion of age *i* fish from cohort *c* that were tagged at age *i* and recaptured in the season directly following release
$\upsilon_{c,i}$	is the reporting rate for age *i* fish from cohort *c*
ξ_g	is the immediate retention rate for tags released by tagger group *g*
Ω_g	is the continuous shedding rate for tags released by tagger group *g*

In terms of the parameterization of the OM:

$$h_{1,c,i} = \sum_{f \in f^1} H_{f,c+a,i}$$

$$h_{2,c,i} = \sum_{f \in f^2} H_{f,c+a,i}$$

In order to evaluate the impact of incomplete mixing of fish tagged close to the Great Australian Bight, a sensitivity run is being considered in which the harvest rate parameters corresponding to season 1 ($h_{1,c,i}$) are increased by a constant factor. Season 1 is when the surface fishery takes place and the hypothesis is that if fish that go to the GAB as juveniles are only a subgroup of the whole population, fish tagged close to the GAB would experiment a higher level of fishing mortality than the population as a whole.

PREDICTED QUANTITIES

Catch-at-age and Catch-at-length

Observations of either catch-at-age or catch-at-length are available for each of the fisheries, and are fitted in the model. The predicted catch-at-age *a* in fishery *f* and year *y* is:

$$\hat{C}_{f,y,a} = s_{f,y,a} F_{f,y} N_{y,a} \quad \text{for} \quad f \in f^1$$

$$\hat{C}_{f,y,a} = s_{f,y,a} F_{f,y} N^*_{y,a} \quad \text{for} \quad f \in f^2$$

For fisheries with length-based data, the predicted catch-at-length *l* in fishery *f* and year *y* is given by:

$$\hat{L}_{f,y,l} = \sum_a p^t_{y,a,l} \hat{C}_{f,y,a} \ \text{ for } \ f \in f^1, t = 1 \ \text{ and for } \ f \in f^2, t = 2$$

where $p^t_{y,a,l}$ is the proportion of fish of age *a* that are length *l* in season *t*, calculated assuming normal distributions for length-at-age with known means and variances.

CPUE

Catch per unit effort (CPUE) is fitted as an aggregate index (i.e. not age-based) for the LL1 fishery only. The relationships between CPUE and abundance and between CPUE and effort allow for a number of non-linear effects. These effects are not estimated in the model fitting procedure, but rather are determined by control parameters input by the user. The predicted CPUE in year *y* is given by:

$$CPUE_y = q_y \tilde{N}_y^{\varpi}\left(1+\beta\left(\frac{E_y - E_{2000}}{E_{2000}}\right)+\gamma\left(\frac{E_y - E_{2000}}{E_{2000}}\right)^2\right)$$

where $\tilde{N}_y = \sum_a \left(\frac{s_{LL1,y,a}}{\text{mean}(S_{LL1,y,a_1},\cdots,S_{LL1,y,a_2})}\right)^{\psi} N_{y,a}$

and $E_y = \frac{C_{LL1,y}}{CPUE_y}$

In this model, parameters $\beta, \gamma, \varpi, \psi, q_y$ and a_1 and a_2 are specified by the user. Current default values are: $\beta = 0, \gamma = 0, \omega = 1, \psi = 1$, $(a_1, a_2) = (4,18)$ or $(8,12)$.
Parameters β and γ: changing the values of β and γ had little or no effect in the conditioning (CCSBT-MP/0304/07).
Parameter ω: Is one of the axes in the grid, with values 1 and 0.75.
Parameters a_1 and a_2 (age range to standardize selectivity for CPUE predictions) are included as one grid axes with two alternative ranges: (1) a_1=4 and a_2=18 (2) a_1=8 and a_2=12. The rational for changing a_2 from 30 to 18 was that selectivities estimated for ages 19-30 are very low.

The only parameter in the above equations that is estimated through the minimization is $\ln(q_y)$ for the first year of the CPUE series. In the current version a fixed 0.5% annual increase in *q* is assumed.

The analyses looking at historical CPUE trend based on a linear increase (CCSBT-MP/0304/07) showed that no improvement was obtained by imposing this relationship. A test assuming a linear increase in catchability of 1% per year throughout the whole time series was examined. This test was later dropped but an increase in *q* of 0.5 % a year (half way between Q0 and Q1) was kept in both the conditioning and in the projections in the core set.

Tag Returns

Let $N_{c,a,g}$ denote the number of fish from cohort *c* tagged at age *a* by taggers in group *g*. We refer to this set of tag releases as set (*c*, *a*, *g*). Let $R_{c,a,g,i}$ be the observed number of fish from release set (*c*, *a*, *g*) that were recaptured at age *i* and had at least one of their tags returned (for simplicity, we will refer to this as the number of tag returns). Then, the predicted number of tag returns is given by

$$\hat{R}_{c,a,g,i} = N_{c,a,g}\, p_{c,a,g,i}$$

Aerial survey

The aerial survey data are treated as a relative index of biomass of age classes 2 to 4, predicted as

$$\hat{I}_i = q_{\text{aerial}} \sum_{a=2}^{a=4} s_a w_{y_i,a} N_{y_i,a},$$

where s_a indicate selectivities-at-age and w_{y_i} are weights at age for season 1 in year *y*. An initial attempt to estimate the selectivity parameters produced unrealistic results. Three alternative fixed selectivity scenarios are available and can be chosen in the control file:

Option	s_2	s_3	s_4
1	1	1	1
2	0.5	1	1

3	0.33	1	0.33

Trolling survey

Treated as a relative index of abundance at age 1.

OBJECTIVE FUNCTION

Likelihood Components for Data Fits

The model is fitted to a CPUE index series, fishery catch-at-age and catch-at-length data, and tag return data. The estimates of total catch for each fishery are assumed to be without error. The negative of the log-likelihood (-lnL) for each of the data components are described below. Note that constant terms of the negative log-likelihood are ignored.

CPUE data

The likelihood is calculated assuming that the observed abundance index (I14) is log-normally distributed about its expected value with variance σ_I^2:

$$-\ln L = n_I \ln(\sigma_I) + \frac{\sum_{y=y_{I1}}^{y=y_{I2}} \left(\ln(I_y) - \ln(\hat{I}_y)\right)^2}{2\sigma_I^2}$$

where y_{I1} and y_{I2} are the first (I4) and the last (I5) years with CPUE data and n_I $(n_I = y_{I2} - y_{I1} + 1)$ is the number of CPUE observations. The variance parameter, σ_I^2, is estimated through the fitting procedure, assuming a normal distribution with a minimum value of $(0.1)^2$.

Catch-at-age and catch-at-length

For fitting to catch-at-age and catch-at-length data a multinomial sampling distribution is assumed. Under this assumption, the log-likelihood function for the catch-at-age or catch-at-length data (in numbers) from each fishery can be written:

$$-\ln L = n_y^f \sum_y \sum_k p_{fyk} \ln(\hat{p}_{fyk})$$

where $k = a$ for catch-at-age data, $k = l$ for catch-at-length data, n_y^f is the effective sample size for fishery *f* in year *y*, and

$$p_{fya} = \frac{O_{fya}}{\sum_a O_{fya}}, \quad \hat{p}_{fya} = \frac{\hat{C}_{fya}}{\sum_a \hat{C}_{fya}} \quad \text{for age-based data}$$

.

$$p_{fyl} = \frac{O_{fyl}}{\sum_l O_{fyl}}, \quad \hat{p}_{fyl} = \frac{\hat{L}_{fyl}}{\sum_l \hat{L}_{fyl}} \quad \text{for length-based data}$$

The O_{fya}, O_{fyl}, $\hat{C}_{fya}$, $\hat{L}_{fyl}$ are the observed and predicted catch-at-age or catch-at-length for fishery *f*. The effective sample sizes, n_y^f, are quantities input for each fishery and year (I41).

Different methods are used for inputting age-frequency and length-frequency data in the SBT conditioning model code. Input of length-frequency data is hard-wired such that the code expects input of data for 110 length-frequency bins each of 2cm width and beginning at 32cm. The user controls the fitting of these data by specifying the minimum length category fitted in the model (I25, fish in bins of smaller length than the minimum are aggregated in the first bin), the width of the length bins used in the fitting procedure (I26, best to specify this in 2 cm increments, consistent with how the data is input), and the number of bins used in the fitting (I27, note that any fish of length greater than the length of the terminal bin are aggregated in the terminal bin). The specified binning values apply to the length-frequency data from all fisheries. An additional option allows for fishery-specific aggregation of a specified number of the smallest length bins seen by the model (I28).

For age-frequency data, the data input controls the age range in the model fit. For each fishery with age-frequency data (I29 and I30) the user specifies the minimum (I31) and the maximum (I32) ages in the data set. The only aggregation of age-classes that is allowed is when the maximum age specified for fitting the age-frequency is the same as the maximum age in the model, which is a plus group.

Tag Returns

If all assumptions of a Brownie tagging model are met (e.g., complete mixing; independence between tagged fish), then the numbers of tags returned at ages *a* to *I*, plus the number not returned by age *I*, corresponding to the $N_{c,a,g}$ releases from release set (*c*, *a*, *g*) have a multinomial distribution; i.e.,

$$\left\{R_{c,a,g,a}\,,\,\dots\,,\,R_{c,a,g,I}\,,\,N_{c,a,g}-R_{c,a,g,\bullet}\right\}\sim\text{Multinom}\left(N_{c,a,g},\left\{p_{c,a,g,a}\,,\,\dots\,,p_{c,a,g,I}\,,1-p_{c,a,g,\bullet}\right\}\right)$$

where a dot in the subscript denotes summation over the index it replaces (e.g., $R_{c,a,g,\bullet}=\sum_{i=a}^{I}R_{c,a,g,i}$).

However, in practice, the tag return data will almost certainly be over-dispersed relative to a multinomial distribution (i.e., more variable). To account for this, we model the tag returns for release set (*c*, *a*, *g*) using a Dirichlet-multinomial distribution, parameterized such that the amount of variance in the data is φ times that of multinomial data (for details refer to Polacheck et al. 2006. Can. J. Fish. Aquat. Sci. **63**: 534–548). Then, the likelihood function for the observed numbers of returns from all release sets is the product of Dirichlet-multinomials.

Specifically,

$$L_R=\prod_c\prod_g\left\{\mathrm{K}_{c.g}\prod_a\left(\frac{\Gamma\left(\omega_{c,a,g}\right)}{\Gamma\left(N_{c,a,g}+\omega_{c,a,g}\right)}\frac{\Gamma\left(R'_{c,a,g,\bullet}+\omega_{c,a,g}p'_{c,a,g,\bullet}\right)}{\Gamma\left(\omega_{c,a,g}p'_{c,a,g,\bullet}\right)}\prod_{i=a}^{I}\frac{\Gamma\left(R_{c,a,g,i}+\omega_{c,a,g}p_{c,a,g,i}\right)}{\Gamma\left(\omega_{c,a,g}p_{c,a,g,i}\right)}\right)\right\}$$

where:

$$\omega_{c,a,g}=\left(N_{c,a,g}-\varphi\right)/\left(\varphi-1\right)$$

$$R'_{c,a,g,\bullet} = N_{c,a,g} - R_{c,a,g,\bullet}$$

$$p'_{c,a,g,\bullet} = 1 - p_{c,a,g,\bullet}$$

$$\mathrm{K}_{c,g} = \prod_a \frac{N_{c,a,g}!}{\prod_{i=a}^{I} R_{c,a,g,i}!(N_{c,a,g} - R_{c,a,g,\bullet})!}$$

Note that $\mathrm{K}_{c,g}$ is a constant that can be omitted when maximizing the likelihood.

The negative log likelihood (leaving off the constant) can then be expressed as

$$\ln L_R = \sum_c \sum_g \sum_a \sum_{i=a}^{I} \Big(\ln\Gamma\big(R_{c,a,g,i} + \omega_{c,a,g} p_{c,a,g,i}\big) - \ln\Gamma\big(\omega_{c,a,g} p_{c,a,g,i}\big) \Big) +$$
$$\sum_c \sum_g \sum_a \Big(\ln\Gamma\big(\omega_{c,a,g}\big) - \ln\Gamma\big(N_{c,a,g} + \omega_{c,a,g}\big) + \ln\Gamma\big(R'_{c,a,g,\bullet} + \omega_{c,a,g} p'_{c,a,g,\bullet}\big) - \ln\Gamma\big(\omega_{c,a,g} p'_{c,a,g,\bullet}\big) \Big)$$

Finally, the negative log likelihood for the tagging model is

$$-\ln L_{tag} = -\ln L_R$$

Simulations with the above model showed that the over-dispersion factor φ cannot be estimated reliably within the likelihood. Thus, we estimate this parameter based on the residuals from the model assuming multinomial returns, as described in the 'Standardized residuals' section below.

Standardized residuals

Under the assumption of multinomial tag return data, the observed number of tag returns at age *i* corresponding to release set (*c*, *a*, *g*) is approximately normally distributed with mean and variance as follows:

$$R_{c,a,g,i} \sim \mathrm{Normal}\Big(N_{c,a,g} p_{c,a,g,i},\ N_{c,a,g} p_{c,a,g,i}\big(1 - p_{c,a,g,i}\big)\Big)$$

Thus, approximate standardized normal residuals can be calculated as

$$\frac{R_{c,a,g,i} - N_{c,a,g} p_{c,a,g,i}}{\sqrt{N_{c,a,g} p_{c,a,g,i}\big(1 - p_{c,a,g,i}\big)}}$$

If the multinomial assumption is correct, the variance of these standardized residuals should be approximately 1. If the variance is in fact *x*, this provides a reasonable estimate of the over-dispersion factor (i.e., $\hat{\varphi} = x$).

Thus, standardized residuals for the Dirichlet-multinomial model can be calculated as

$$\frac{R_{c,a,g,i} - N_{c,a,g} p_{c,a,g,i}}{\sqrt{\hat{\varphi} N_{c,a,g} p_{c,a,g,i} \left(1 - p_{c,a,g,i}\right)}}$$

An estimate of φ was calculated using the tag residuals obtained from each cell of the grid under the assumption of multinomial tag returns, and was found to range from 2.2 to 2.9 with a mean of 2.35.

Aerial survey

A log-normal likelihood with autocorrelated error and added process error was used:

$$-\ln L_{\text{aerial}} = 0.5 \quad \ln|\Sigma| \; + \; 0.5 \quad res^T \Sigma^{-1} res$$

where

$res = \ln(I) - \ln(\hat{I})$ is a vector of residuals computed using a maximum likelihood estimate of the log of the proportionality coefficient

$$\ln \hat{q}_{\text{aerial}} = \frac{1^T \Sigma^{-1} res}{1^T \Sigma^{-1} 1}$$

and $\Sigma = S + 1 \; \tau^2_{\text{aerial}}$ is a variance-covariance matrix with S the empirical variance-covariance matrix for the logged survey indices and τ_{aerial} an estimated parameter representing added process error (which would impact projections for MP considerations).

Trolling survey

This index (for 1996 onwards) is used in sensitivity trials. A normal likelihood with constant estimated variance σ^2_{piston} is assumed.

Likelihood Components for Priors

Stock-recruitment relationship

The stock-recruitment relationship used in the SBT model requires prior assumptions about the stock-recruitment steepness parameter, the magnitude of the change in carrying capacity, and the magnitude of the recruitment residuals. The steepness parameter can either be fixed (I9<1) or estimated in the analysis (I9 ≥ 1). When estimated, the steepness is assumed to be normally distributed $h \sim N\left[\tilde{h}, 0.1^2\right]$, but the user can specify a tighter area of support (i.e bounds, I10 and I 11) than would be expected for a normal distribution. The negative log-likelihood for the steepness prior is:

$$\frac{\left(h - \tilde{h}\right)^2}{2\left(0.1\right)^2} \quad \text{where } \tilde{h} = 0.5*(\text{I10+I11})$$

A normal distribution (in log space) is also assumed for the stock-recruitment residuals, $\tau_y \sim N\left[0, \sigma_R^2\right]$. The variance of the residuals can either be fixed (I12 <1, σ_R =I12) or estimated (I12 ≥ 1). In either event, the negative log-likelihood for the normal distribution prior is:

$$\left(y_{n2} - y_{n1} + 1\right)\ln\left(\sigma_R\right) + \frac{\sum_{y=y_1+1}^{y=y_n+1} \tau_y^2}{2\sigma_R^2} \ .$$

Note that when estimated there is a lower bound of 0.4 on the σ_R parameter.
The likelihood assumes no autocorrelation except for the last three years (e.g. 2007-2009 when the last year of data is 2008). The empirical autocorrelation of recruitment residuals estimated over the period 1965-2003 is applied from 2007 onward. Let τ_y represent the lognormal recruitment deviate in year *y* and $\hat{\tau}_y$ its MPD estimate. The initial abundances passed to the projection code (when troll data are not included) correspond to

$\hat{\tau}_{2006}$ estimated from model fit

$\hat{\tau}_{2007} = \rho\hat{\tau}_{2006}$

$\hat{\tau}_{2008} = \rho^2\hat{\tau}_{2006}$

$\hat{\tau}_{2009} = \rho^3\hat{\tau}_{2006}$

where $\hat{\rho}$ is the empirical estimate of autocorrelation based on recruitments for years 1965-2003.

An uninformative prior is assumed for the change in the carrying capacity (*i.e.* uniform), so the contribution to the objective function is a constant.

<u>Selectivity</u>

The age-specific selectivity parameterization incorporates two type of assumption that reflect prior belief about the form of the selectivity function. For all fisheries either a dome-shaped or linear relationship between selectivity and age can be specified. The negative log-likelihood for the prior is:

$$\sum_f g^f\left(x_{fya};\sigma_{b^f}^2\right)$$

where the variance term, $\sigma_{b^f}^2$ (I37), reflects belief about the degree to which the selectivities for fishery *f* follow the expected shape (domed or linear).

For some or all fisheries, the age-specific selectivity functions can change over time. The amount of change is controlled by input parameters (fishery and year specific, I40) related to the variance of the changes $\left(\sigma_{S_y^f}^2\right)$.

$$\sum_f \sum_{y \in c^f} \frac{\left(\gamma_{fya}\right)^2}{2\sigma_{S_y^f}^2}$$

where c^f is the set of years in which selectivity changes for fishery *f*. Note that for fisheries with time-invariant selectivity this set will be empty.

<u>Natural Mortality</u>

Additional components are added to the likelihood function if natural mortality at ages 1 and/or 10 are also estimated. In that case normal prior distributions are assumed for both parameters. The negative log-likelihoods for these priors are:

$$0.5\frac{(m^{1}-0.4)^{2}}{0.04^{2}} \text{ and } 0.5\frac{(m^{10}-0.10)^{2}}{0.06^{2}}$$

Table 1. Fixed quantities determined through model inputs.

Quantity	Description	Control file code
y_{n1}, y_{n2}	first and last years for reconstruction	I1, I2
y_{c1}	first year for catch data	I3
y_{I1}, y_{I2}	first and last years for CPUE index data	I4, I5
y_{AC}	the year that initiates serial correlation in the stock-recruitment residuals	I13
$\boldsymbol{A}$	last age class in model	I6
	number of fisheries	I7
a_f^{mins}, a_f^{maxs}	minimum and maximum age-class for which selectivity parameters are estimated for fishery f	I34, I35
f^1, f^2	the set of fisheries in season 1 and in season 2	I33
c^f	the set of years in which selectivity changes for fishery f	I40
$\boldsymbol{z}$	the set of fisheries where selectivity for fish older than a_f^{maxs} is equal to that of a_f^{maxs}	I36
$\beta, \gamma, \varpi, \psi,$ q_y, a_1, a_2	parameters determining the relationship between CPUE and stock abundance	I16, I17, 118, I19, I20, I21, I22
ν	stock-recruitment depensation parameter	I23
κ	parameter for non-linear body weight-reproductive potential relationship	I24a
h	stock-recruitment steepness parameter (Note: also can be estimated)	I9 $\geq$ 1, then $h = 0.5(\text{I10+I11})$
M_a	natural mortality (Note: also can be estimated)	I8a
m_a	fraction mature at age	
σ_R^2	variance of stock-recruitment residuals (Note: can be estimated)	I12<1
$\sigma_{b^f}^2$	variance for the shape of the selectivity function for fishery f	I37
$\sigma_{S_y^f}^2$	variance of the selectivity change in year y for fishery f	I40
n_y^f	multinomial sample size for length or age sample from fishery f in year y	I41
φ	over-dispersion factor for tagging Dirichlet-multinomial	

Table 2. Quantities “hardwired” in code (i.e. you will need to change the code if you want to change these)

Quantity	Description
b_a	proportion of fish mature at age a
w_{fya}	mean weight at age a in fishery f in year y – dependent on input mean lengths-at-age, but weight-length relationship for each fishery is hardwired
w_{ya}^s	mean weight of spawning fish at age a in year y is set equal to mean weight-at-age for fishery 1 (LL1 fishery)
ϖ	empirical correlation of S-R residuals used in “hard-wired” AC is based on residuals from 1966 to last year of data minus 5. It is applied from control parameter rec_AC_sw onwards (usually set to last year of data minus 1)

Table 3. Quantities estimated through the function minimization. Note that with the exception of the stock-recruitment steepness parameter and the variances of the stock-recruitment residuals and the selectivity changes, the prior distributions are "hardwired" in the code. (ie. you will need to change the code if you wish to change the prior).

Quantity	Description	Prior
B_0^r	Equilibrium spawning stock biomass in the absence of fishing for regime r	$B_0^r \sim U[0,\infty]$
h	stock-recruitment steepness (Note: can also be a fixed quantitiy)	$h \sim N\left[\tilde{h},\ 0.1^2\right]$ $\tilde{h} = 0.5*(\text{I10+I11})$
$\bar{q}$	Log of catchability	$U[-\infty,\infty]$
$\ln \hat{q}_{\text{aerial}}$	logarithm of "catchability" of aerial survey	$U[-\infty,\infty]$
τ_{aerial}	standard deviation of added process error for aerial survey	$U[0,0.8]$
m^1	natural mortality at age 1	$N(0.4,0.4^2)$
m^4	natural mortality at age 4	$U[m^1,m^{10}]$ or fixed
m^{10}	natural mortality at age 10	$N(0.1,0.6^2)$
m^{30}	natural mortality at age 30	$U(0.20,0.50)$ or fixed
δ_y	parameters related to the stock-recruitment residuals – note that the prior distribution is for the s-r residuals, τ_y, not the estimated parameters	$\tau_y \sim N\left[0,\sigma_R^2\right]$
λ_{fa}	selectivity parameter for age a in fishery f	$\lambda_{fa} \sim U[0,\infty]$
γ_{fya}	logarithm of the parameter governing the change in selectivity at age a in year y and fishery f	$\gamma_{fya} \sim N\left[0,\sigma_{S_y^f}^2\right]$
σ_I^2	variance of the CPUE index data	$\sigma_I^2 \sim U[0.2,\infty]$
σ_R^2	variance of stock-recruitment residuals (fixed in reference set)	$\sigma_R^2 \sim U[0.4,\infty]$
$h_{1.c.i}^*$	proportion of age *i* fish from cohort *c* that were tagged at age *i* and recaptured in the season directly following release	
$\upsilon_{c,i}$	Tag reporting rates for fish of age *i* cohort *c*	

Projection model

Model Structure

Same as in conditioning model except that only four fisheries are considered:

1: LL1 fishery (second season).
2: LL2 fishery (second season).
3: Indonesian spawning fishery (first season).
4: Australian surface fishery (first season).

Population Model

Same as in conditioning model.

Initial abundances

Initial abundances at the start of the projection are estimated by the conditioning model. Lognormal autocorrelated error is added to the initial abundances at ages 0 through 2 within the projection code to represent process error affecting recruitment. Let Y_1 be the first year of the projections, then

$$N_{Y_1,4} = \hat{N}_{Y_1,4} \exp\{0.4z - 0.08\}$$
$$N_{Y_1,3} = \hat{N}_{Y_1,3} \exp\{0.4z - 0.08\}$$
$$N_{Y_1,2} = \hat{N}_{Y_1,2} \exp\{\varepsilon_{Y_1-2}\}$$
$$N_{Y_1,1} = \hat{N}_{Y_1,1} \exp\{\hat{\rho}\varepsilon_{Y_1-2} + \varepsilon_{Y_1-1}\}$$
$$N_{Y_1,0} = \hat{N}_{Y_1,0} \exp\{\hat{\rho}^2\varepsilon_{Y_1-2} + \hat{\rho}\varepsilon_{Y_1-1} + \varepsilon_{Y_1}\}$$

where $z \sim N(0,1)$ and $\varepsilon_y \sim N(0,(1-\hat{\rho}^2)\sigma_R^2)$, where σ_R =0.6. Note that log-normal error with s.d.=0.4 has been added to account for uncertainty around $\hat{N}_{Y_1-4,0}$ and $\hat{N}_{Y_1-3,0}$.

These equations imply that:

$$\tau_{Y_1} = \hat{\tau}_{Y_1} + \hat{\rho}^2\varepsilon_{Y_1-2} + \hat{\rho}\varepsilon_{Y_1-1} + \varepsilon_{Y_1}$$

which is used to generate $\tau_{Y_1+1} = \hat{\rho}\tau_{Y_1} + \varepsilon_{Y_1+1}$ and so on.

This formulation amounts to assuming autocorrelated recruitment starting in Y_1-2. It was noted that because point estimates from the different grid cells are used for projections (instead of a full Bayesian approach) this method tends to propagate the Y_1-3 recruitment deviate into the future without properly reflecting its uncertainty. To address this problem, a sensitivity run is included in which the recruitment deviate for Y_1-2 is uncorrelated to the previous deviates.

Selectivities

Random-walk processes as assumed in conditioning are not appropriate because they may result in the selectivities wandering off into implausible regions. Instead, the current projection model starts with most recent estimates of selectivity and adds autocorrelated process error according to:

$$s_{1,a,y+1} = s_{1,a,y} \exp\{\varepsilon_{a,y}\} \quad \text{for} \quad a_1^{\min s} \geq a \geq a_1^{\max s} \quad \text{where} \quad a_1^{\min s} = 2,\ a_1^{\max s} = 17$$

$$\varepsilon_{2,y} = \eta_{2,y}$$

$$\varepsilon_{a+1,y} = \rho_{\text{sel1}}\,\varepsilon_{a,y} + \sqrt{1-\rho_{\text{sel1}}^2}\,\eta_{a,y}, \quad \text{where} \quad \eta_{a,y} \sim N(0,0.2^2) \quad \text{and} \quad \rho_{\text{sel1}} = 0.7$$

(note that first subscript corresponds to fishery *f*=1). Selectivities only change every four years so that $s_{1,a,y+3} = s_{1,a,y+2} = s_{1,a,y+1} = s_{a,y}$.

It was note that the SAG9 model specifications resulted in a bimodal selectivity estimated for 2006 and 2007. In previous years the end-year selectivity was from a 4-year block. The SAG9 concluded that given the changes in management, the use of the average of the last 3 years (2006-2008) will be more appropriate.

For the Australian surface fishery, lognormal variability combined with targeting on age 3 is assumed as follows:

Define

$$P_{y,3} = \frac{N_{y,3}}{\sum_{a=1}^{5} N_{y,a}} \quad \text{and} \quad \overline{P}_3 = \frac{1}{10}\sum_{y=y_{n2}-9}^{y=y_{n2}} P_{y,3}$$

If $P_{y,3} \geq \overline{P}_3$,

$$s_{6,y,3} = s_{6,y_{n2},a}\,\mathrm{e}^{\varepsilon_{6,y,a}} \text{ for } a = 1,\ldots,5 \text{ where } \varepsilon_{6,y,a} \sim N(0,0.1^2).$$

Otherwise, increase selectivity of age 3:

$$s_{6,y,3} = s_{6,y_{n2},a}\,\mathrm{e}^{\varepsilon_{6,y,a}}\left(1 + 0.5\frac{\overline{P}_3 - P_{y,3}}{\overline{P}_3}\right)$$

$$s_{6,y,3} = s_{6,y_{n2},a}\,\mathrm{e}^{\varepsilon_{6,y,a}} \quad \text{for } a = 1,2,4,5.$$

CPUE

CPUE is generated using autocorrelated trends in catchability over-imposed to the 0.5% annual increase in q. The empirical estimate of autocorrelation based on the entire time series (1969-2006) is used. For the sigma: use a value of 0.2 or the empirical estimate for the entire time series, whichever is largest. Alternatively, the user can select a value as a command option to the projection code by typing

-cpuestd xx

Attachment 7

Structure and conditioning of the operating model

As part of the agenda item 2, Reconsideration of Operating Models some of the details for the process of restructuring and re-conditioning the operating model follow.

By way of background, the previous specification of axes to be considered for the new "grid" are shown here:

	Levels	Cumul N	Values			Prior	Simulation Weights
Steepness (*h*)	3	3	0.385	0.55	0.73	0.2, 0.6, 0.2	Prior
M_0	3	9	0.30	0.40	0.50	Uniform	Prior
M_{10}	3	27	0.07	0.1	0.14	Uniform	Prior
Omega	2	54	0.75		1	0.4, 0.6	Prior
CPUE ()	2	108	w.5	w.8		Uniform	Prior
q age-range	2	216	4-18		8-12	0.67, 0.33	Prior
Sample Size	2	432	Sqrt		Original/2	Uniform	Prior

Each of these components and other structure aspects (e.g., treatment of tagging data) were evaluated for candidacy for future OMP runs. These follow roughly the order of discussions held at the meeting.

Natural mortality

The operating model specifications for natural mortality with age were re-evaluated in two parts: the young component (affected by tagging data) and the older ages contributing to the plus-group (25 and older).

Mortality on older ages. SAG9 highlighted a problem with the current operating model grid where for some cells (especially the low m^{10}cases), the estimated spawning biomass was much higher than for other cells and consisted almost entirely of SBT age 30 years and older. Below is an example of a few cells from some base runs examined at SAG9.

Scenario	Unfished SSB (SSB_0)	SSB_{2008}	SSB_{2008}/ SSB_0
Low *m*	1,708,550	225,323	0.132
High *m*	651,982	56,943	0.087
Low m^0, **High** m^{10}	779,301	71,012	0.091

This high biomass of old animals was not apparent in the fits to the age composition of the Indonesian catch because the estimated selectivity of the Indonesian fishery was very dome-shaped, with estimated selectivity at age 30+ = 0.008 (when normalized to maximum of 1; Fig. 1).

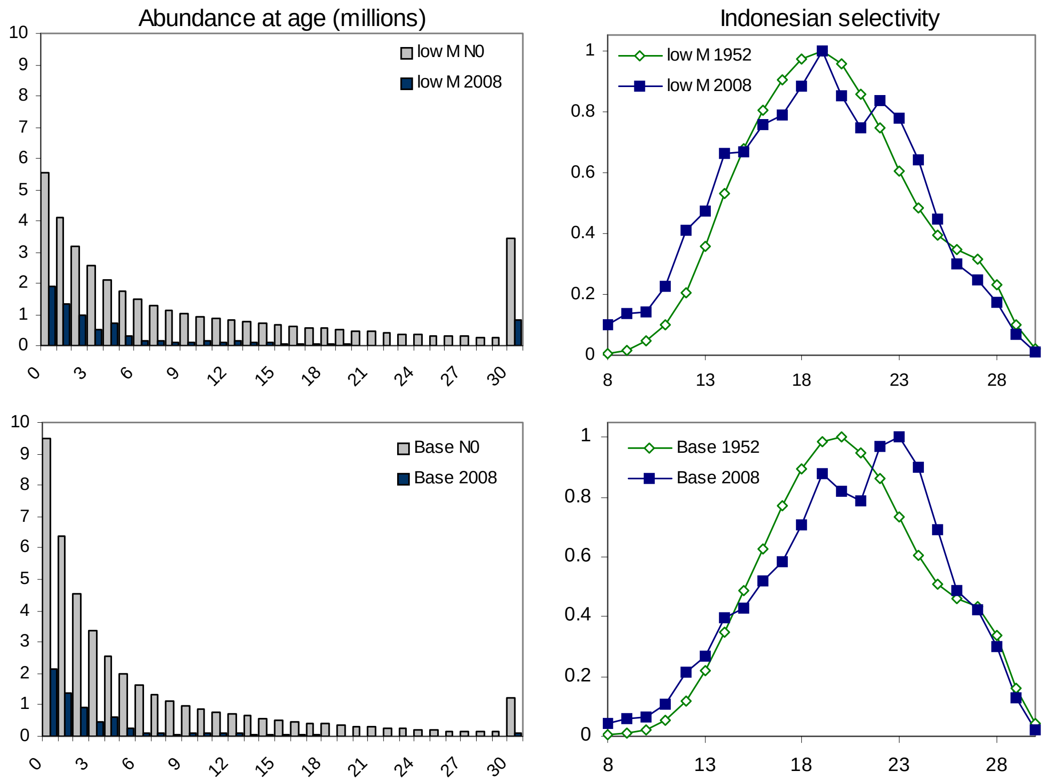


Figure 1. Example of estimated abundance at age and Indonesian selectivity obtained with the operating model used at SAG9 in 2008.

Based on a simple evaluation of the available age-specific catches of SBT older than age 30 (ranged from 30-41 years) the total mortality estimated for the plus group using a standard catch-curve analysis was on the order of 0.47 (Fig. 2). The fishing mortality on this group was considered to be small and therefore the natural mortality would have to be much higher than assumed in the base model (M_a assumed constant for ages older than 10 at values of 0.07, 0.10 and 0.14) to accommodate these data.

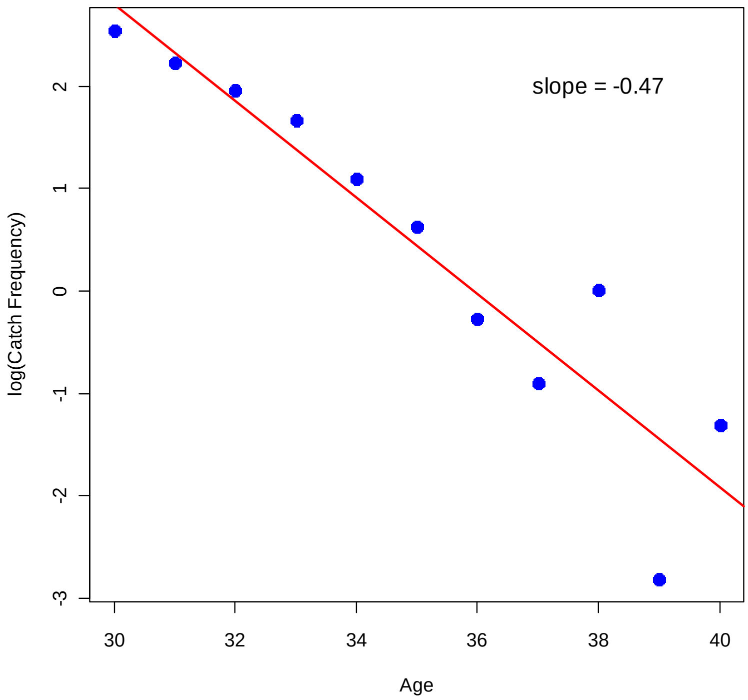


Figure 2. Fit to the logarithms of total age-specific catch estimates from the Indonesian fishery ages 30-40, 1993-2007. Note that the data being used were taken from the CCSBT data exchange item AU: Indonesian LL Age Size Composition.

This result stimulated development of measures to re-structure the age-specific natural mortality schedule to better reflect the apparent senescence of older SBT (as opposed to the alternative that a cryptic, "plausible" old biomass from the population persists and contributes substantively to the spawning population). The following table shows the array of alternative natural mortality schedules that were evaluated while assuming that the relative availability/selectivity of fish older than age 25 was constant. Age transition refers to the age after which mortality begins to change, and m^{30} is the natural mortality assumed for the "plus group" based on the catch-curve analysis. The shadings of the cells represent changes from the "reference" line. Note that none of these "trial names" are carried forward but were specified here for clarity only.

Trial name	m^0	m^{10}	Age Transition	m^{30}
Previous structure	0.3	0.10	-	0.1
Reference	0.3	0.10	20	0.4
Plus group senesce	0.3	0.10	29	0.4
Int Transition	0.3	0.10	25	0.4
Int Trans, High m^{10}	0.3	0.14	25	0.4
Low Age30	0.3	0.10	20	0.2
Low m^{10}	0.3	0.07	20	0.4
High m^{10}	0.3	0.14	20	0.4
High m^0	0.5	0.10	20	0.4

The results of these trial runs indicated that it would be difficult to use a fix grid on m^{30} because some of the high-M combinations resulted in selectivities that increased exponentially at older ages, a pattern considered unrealistic. A set of additional runs were proposed where the value of m^{30} was estimated conditioned on the same range of fixed values of m^{10}. The properties of the estimation over the grid were good (reasonable estimates and standard errors) and reflected an inverse correlation between m^{30} and m^{10}. Hence, the WG noted that adding the feature to estimate the value of m^{30} improved the structure and avoided implausible characteristics of the operating model grid. The WG discussed at length whether an age-transition of 20 years or 25 years was more appropriate. In practical terms, the model-result differences between these were minor. The WG decided that an age of 25 years was more appropriate biologically than an age of 20 years to represent a transition towards senescence.

Figure 3 shows an example suite of diagnostic figures under the old structure (top three rows of figures) and the revised structure (bottom three rows). Note that in the earlier configuration, some grid specifications indicated that nearly all of the spawning biomass was in the "30+" group. The revisions resolved this and had more credible selectivity patterns for the Indonesian fishery. During this exercise, the smoothness aspect of the Indonesian selectivity was also adjusted to avoid added age-age variability in the non-parametric selectivity estimates.

Mortality on younger ages. In the old model, mortality was assumed to be a power function of age from ages 0 to 10 and constant at ages older than 10

$$M_a = \begin{cases} m^0 + (m^{10} - m^0)\dfrac{a^\kappa}{10^\kappa} & \text{for } 0 \le a \le 10 \\ m^{10} & \text{for } a > 10 \end{cases}$$

The parameter κ was fixed at a value of 0.7, and the m^0 and m^{10} parameters were fixed at three different values specified in the grid.

A number of runs were conducted in which the power parameter κ was estimated (instead of being fixed) conditioned on all 9 combinations of values for m^0 and m^{10}. The results of these runs indicated that mortality at age 4 was well determined by the data (Fig. 4; note convergence of mortality schedules around age 4 when κ was estimated). Based on these results the WG decided to estimate a new parameter m^4 specifying the natural mortality at age 4, and to linearly interpolate the natural mortalities between ages 1 and 4 and between ages 4 and 10 (see equations in Attachment 6). Natural mortality at age 0 was assumed to be equal to that of age 1, and a new set of m^1 values of 0.25, 0.30, 0.35 and 0.4 was evaluated. The likelihood of the two extreme values was found to be very low and so only the two intermediate values were kept in the final grid. An example of the final form specified for the OMP is given in Figure 5.

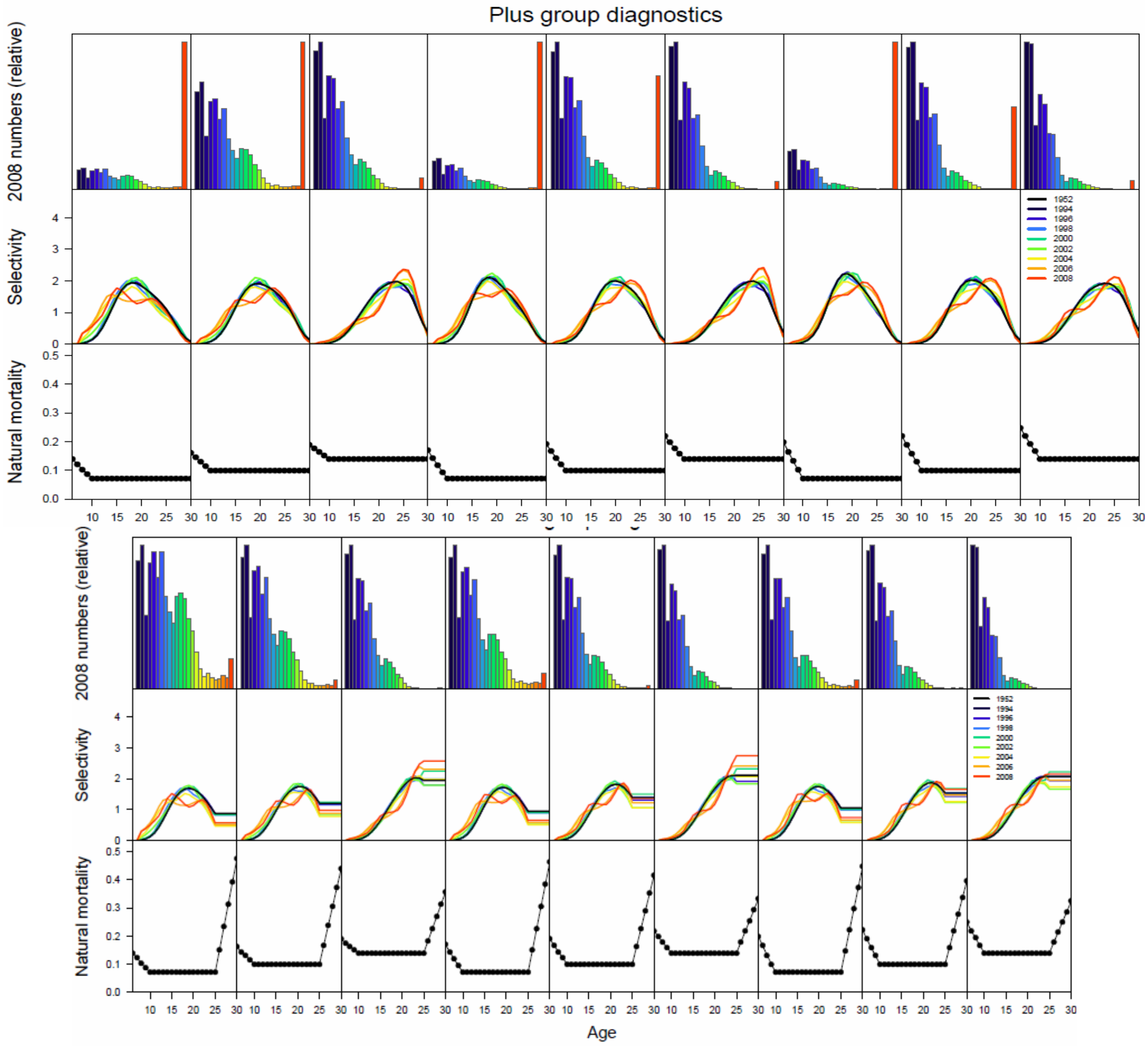


Figure 3. Example of figures used for “plus-group diagnostics” where the top row shows estimates of 2008 numbers-at-age, the second row shows the selectivity estimates for the Indonesian fishery, and the third row shows alternative input vectors of natural mortality. The top three rows correspond to the model results prior to re-structuring compared to the bottom three panels where alternative structure for age-specific natural mortality is introduced.

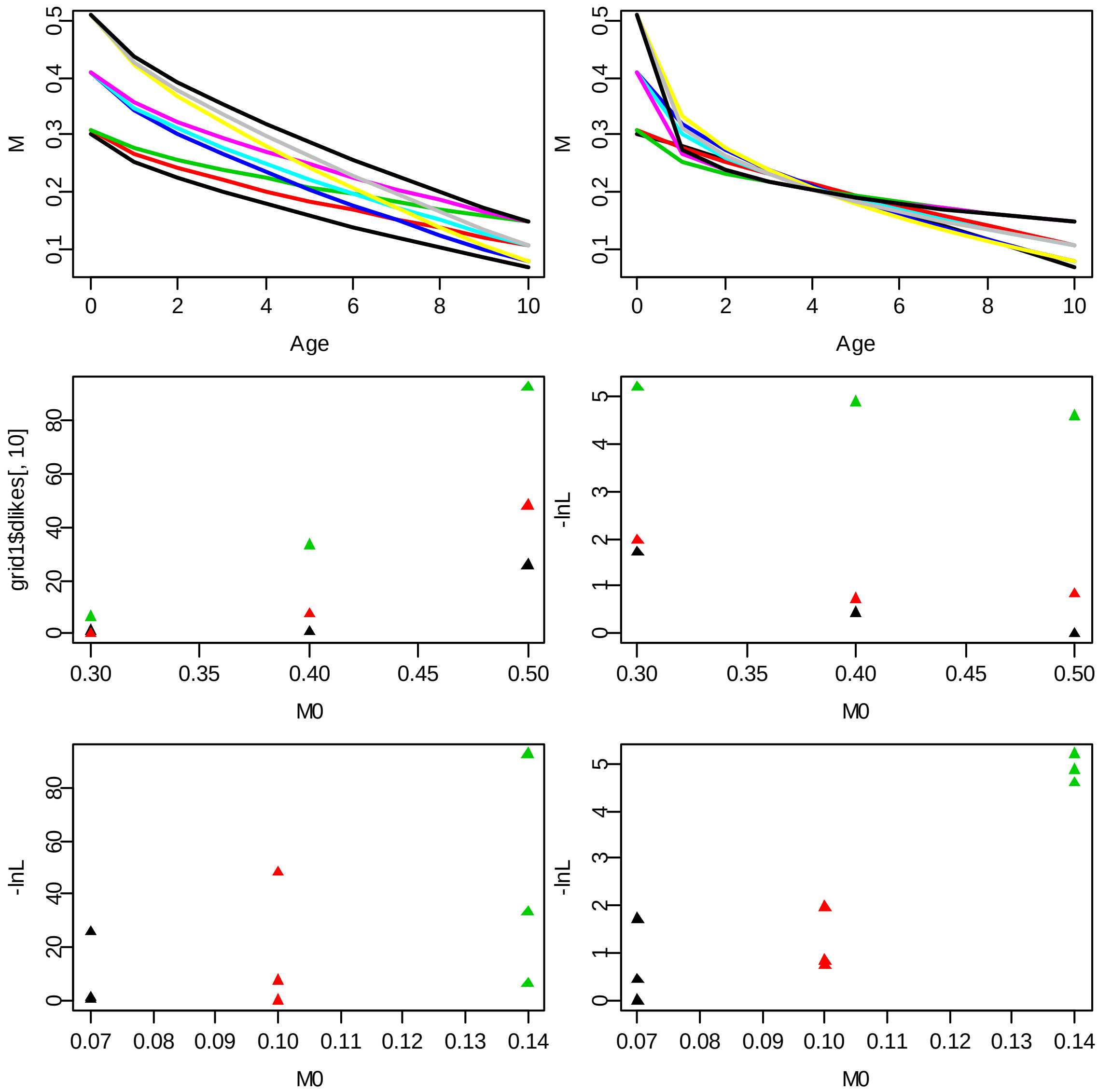


Figure 4. Comparison of mortality schedules and likelihood values for different values of m0 and m10 while using a fixed "power" parameter as in the old model structure (left panels) and with the power parameter estimated (right panels).

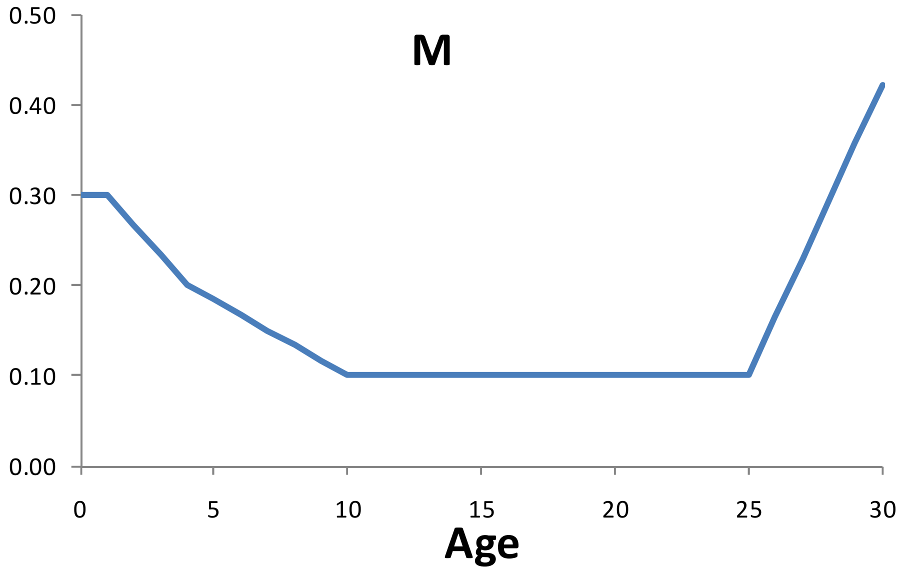


Figure 5. An example result for age specific natural mortality (*M*) where M_1 = 0.3, M_{10} =0.10, and M_4 and M_{30} freely estimated.

Steepness

With the new tagging likelihood and other changes, the likelihood-weighted operating model indicated that higher values of steepness were apparent compared to previous model configurations (Fig. 6). The possibility of increasing the values of steepness used in the grid was discussed but a decision was deferred for the SC, after the full range of possible steepness values is evaluated in connection with the choice of m^{10}.

Tagging data

There was extensive discussion about mixing, particularly between releases from the Great Australian Bight (GAB) and Western Australia (WA). The implications of these data and assumptions relative to fishing mortality estimates concerns mixing levels and site fidelity for younger fish.

The tag model assumes complete mixing between tagged and untagged fish after the first year of release. To try to evaluate this assumption (i.e., to evaluate the degree of mixing), the WG requested an analysis of tag return rates in the Japanese LL fishery in statistical areas 7, 8 and 9. Plots of the number of tags returned per 1000 fish caught for ages 2 to 5 showed, in general, higher return rates from area 7 (Fig. 7). This is suggestive of incomplete mixing, although other factors may also contribute (such as different reporting rates between areas, different levels of possible unreported catches between areas, etc.). The WG noted that if only a fraction of the overall population is available to tagging close to the GAB, then incomplete mixing could result in biased estimates of F.

A sensitivity run to address lack of tag mixing was proposed. For modelling the tagging data component: investigate a range of proportional increases in the season-1 *F*'s (*H*) (during which the surface fishery occurs) in the tagging likelihood as a first approximation to address the effect of incomplete mixing (See Attachment 6).

CPUE

After evaluation of the shade plots showing the results of the sampling of cells over the grid, the workshop agreed that there was little support for lower values of omega and suggested that the value of 0.75 be run as a sensitivity but not as part of the base grid. As alternative CPUE series are used, there was interest to investigate the interaction of Omega with other series.

Relative weights (sample size)

The distribution of the standard deviation of normalized residual for the grid showed that some components (LL2 and LL4) had too much weight relative to the other datasets (Fig. 8). The WG thought that less weight should be given to these components and that this should be part of the OM re-specification. The sampled sized for these two fisheries were reduced by ¼ which resulted in standard deviations of the normalized residuals more in line with those of the other fishery components (Fig. 9).

In the old grid, two sets of sampled sized (called sqrt and orig.5) were used for conditioning the operating model. The differences between these two sets in constant catch projections integrated over the other grid axes appeared minor (Fig. 10). The WG selected the sqrt case for future OMP specifications. As an aside, development of residual plots for comparing how alternative model specifications changed residual patterns was developed (Fig. 11).

Aerial survey

The WG considered that the inclusion of the covariance between the aerial survey indices was adequate. The downside of using the additional covariance structure was that it required extra computations that may be of limited value since this index is quite noisy to begin with (CVs on the order of 25%). The fact that the estimates for Tau-aerial (added process noise) was almost zero (lower than the initial values) in all cases, fixing this value to zero would speed up calculations with minimal effect on model results. All grid cells of the conditioned operating model fit the time series of aerial survey data poorly (Fig. 12). The group considered that due to concerns over the variable quality of the index in some years an alternative grid specification that fit this series better was not worth pursuing.

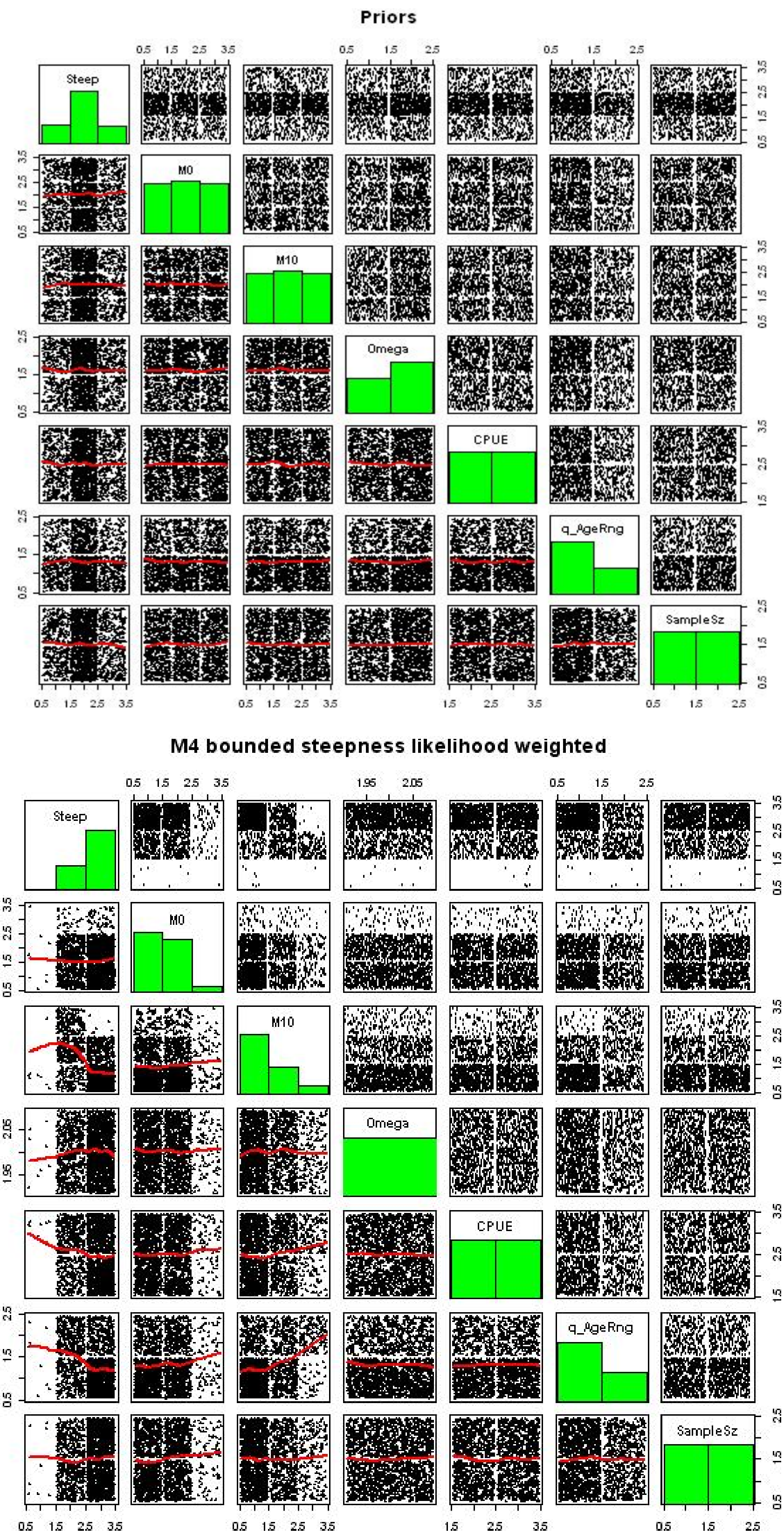


Figure 6. Shade-plots showing the prior-weighting (top panel) compared to likelihood-based weightings for steepness and natural mortality parameters (bottom panel). Note low likelihood of low stepness value.

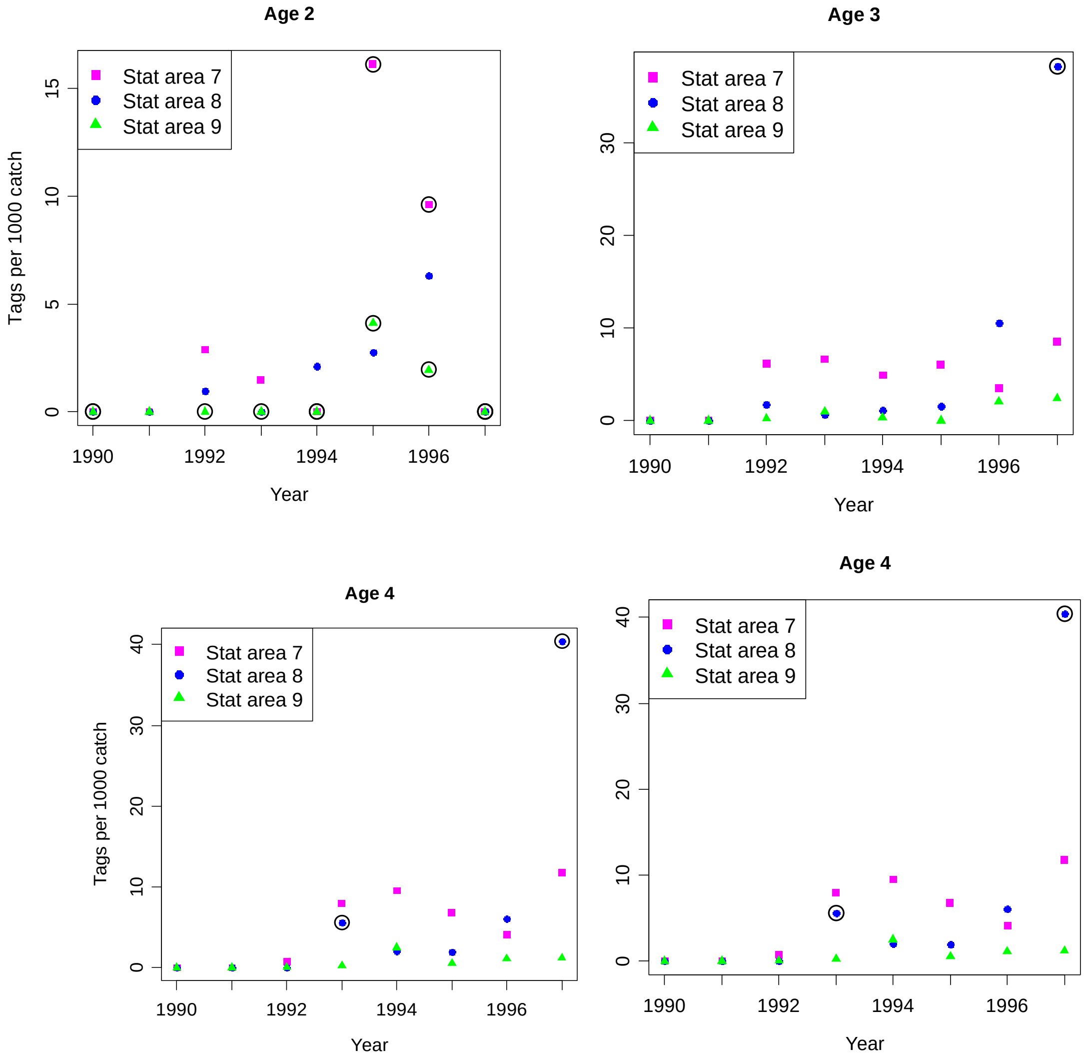


Figure 7. SBT tagging results showing the number returned per 1000 SBT caught in the Japanese LL fishery in statistical areas 7 to 9, for fish of ages 2 to 5. Points surrounded by a black circle indicate points where the catch was less than 1000. Note that tag returns in the year of release are omitted in order to allow for a period of mixing (since fish tagged in the GAB may become available to the fishery in area 7 sooner than they would become available to the fishery in areas 8 and 9).

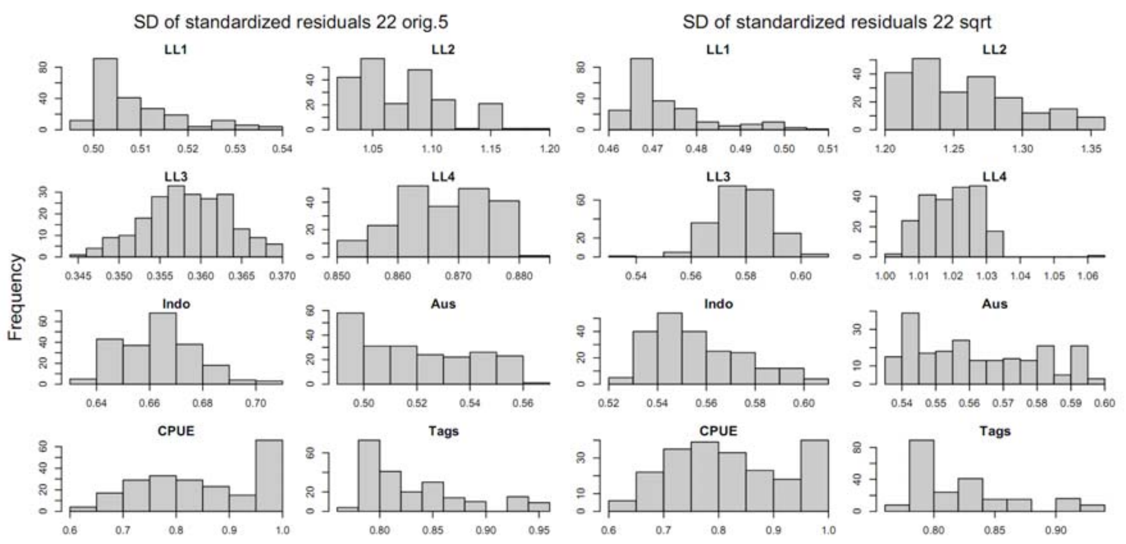


Figure 8. Frequency histogram of gridded values of standard deviations of residuals by data components for sample size set to "orig.5" (1st and 2nd panels) compared to sample size set to "sqrt" (3rd and 4th panels).

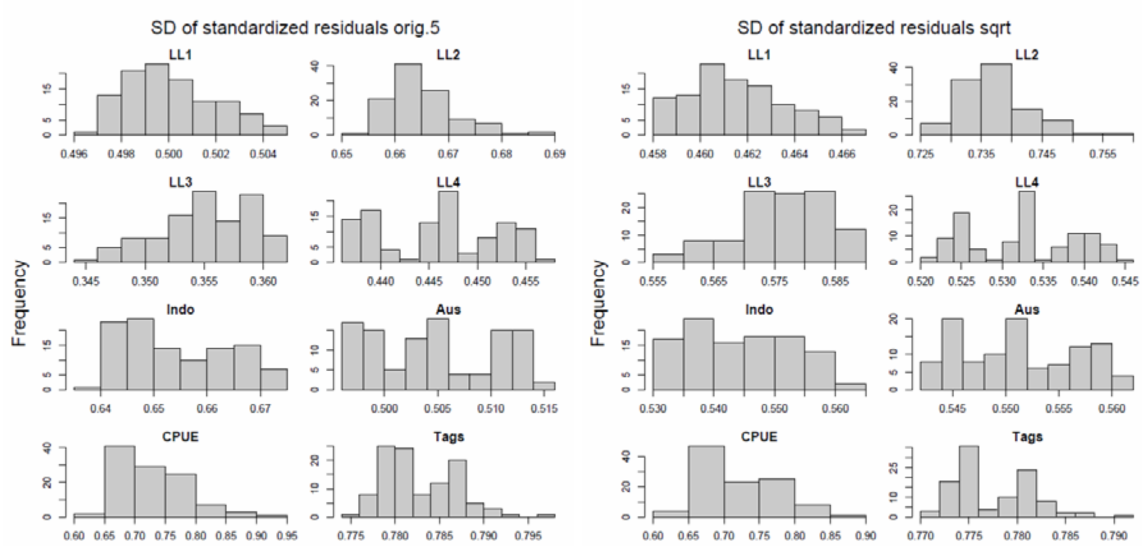


Figure 9. Frequency histogram of gridded values of standard deviations of residuals by data components for sample size set to "orig.5" (1st and 2nd panels) compared to sample size set to "sqrt" (3rd and 4th panels) after downweighting LL2 and LL4.

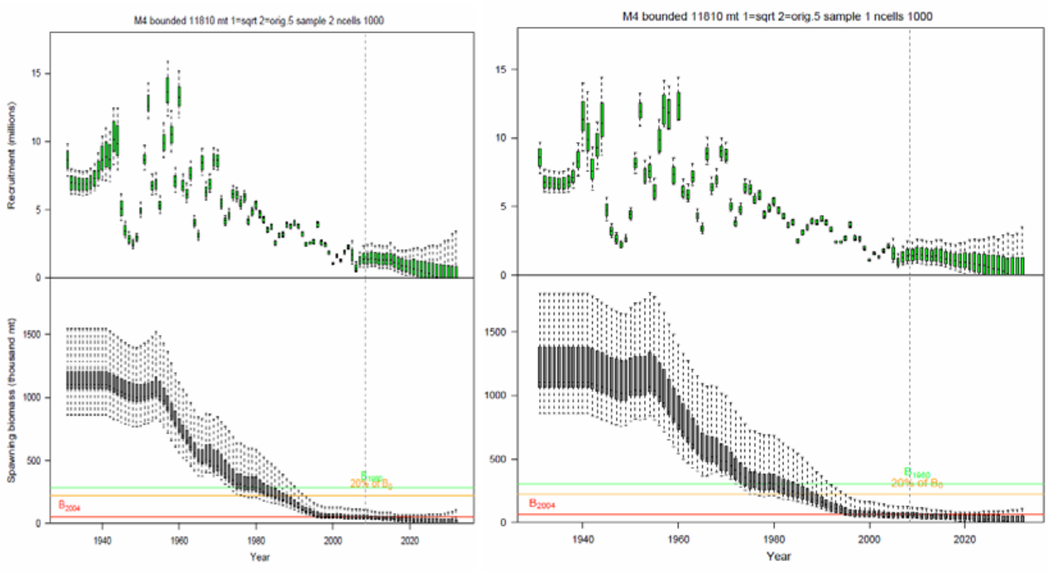


Figure 10. Comparison of grid results (natural mortality weighted by likelihoods) for conditioned grids with sample size set to “orig.5” (left panels) compared to sample size set to “sqrt” (right panels).

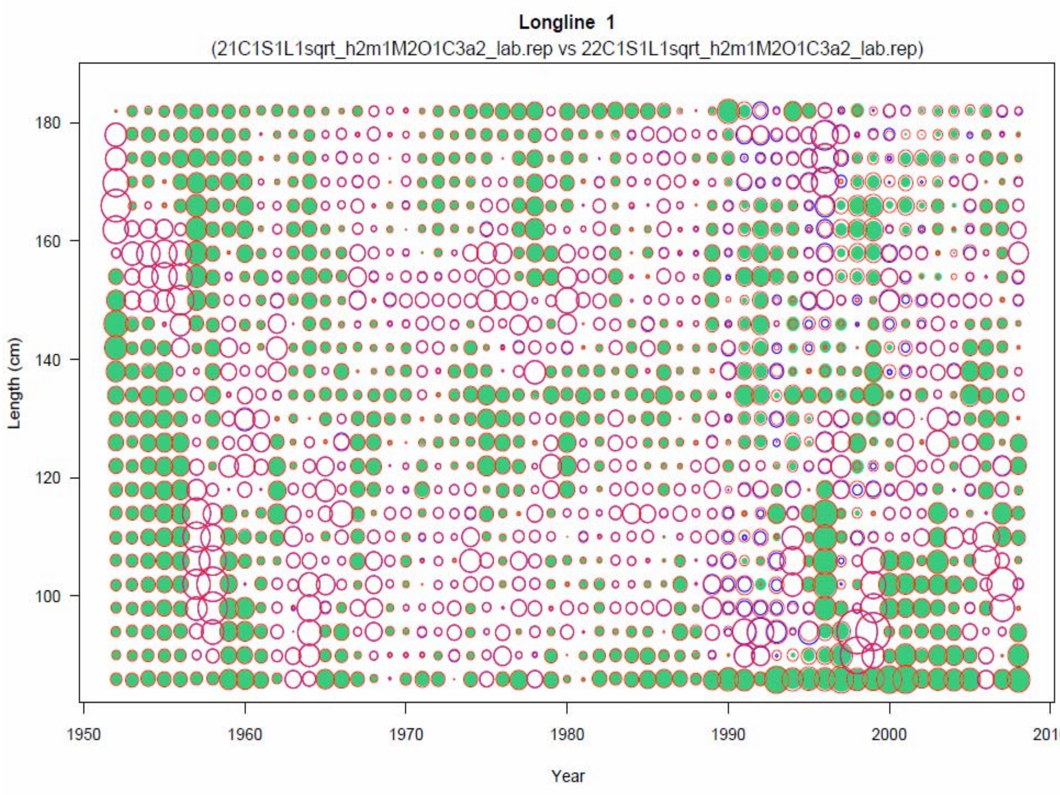


Figure 11. Example comparing normalized residual patterns to longline fishery 1 where solid circles are negative residuals and open circles are positive residuals. Blue circles are residuals from the alternative model. In this case the models sbtmod 21 (old tag likelihood structure) and sbtmod22 (new tag likelihood structure) were being compared for some intermediate choice of the grid.

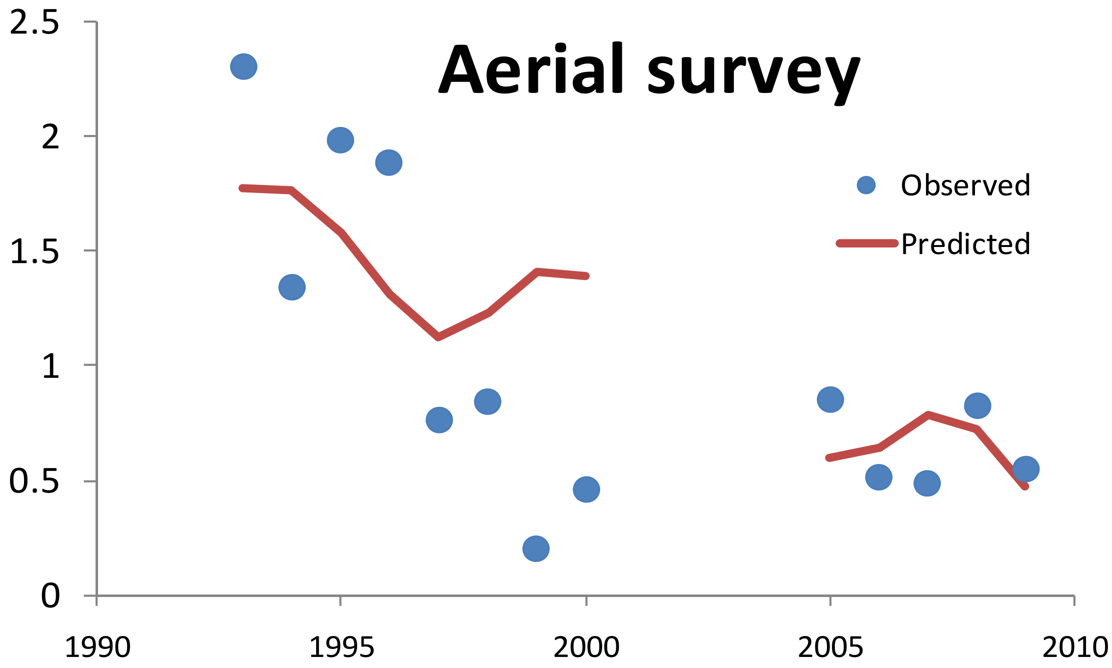


Figure 12. Example fit to aerial survey data.