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The effect of smoothed catch per unit effort on projections of spawning stock biomass for southern bluefin tuna

A Retrospective Study

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Summary

In recent years, longline catch per unit effort (CPUE) indices for southern bluefin tuna (SBT) have varied more between years than was previously the case. The different indices used to monitor CPUE have also suggested quite different trends in relative biomass in some cases. At the same time there has been a perception that projections of future spawning stock biomass (SSB) of southern bluefin tuna have been excessively variable from one year to the next. This paper examines the extent to which interannual variation in CPUE inputs contributes to this variation and the effect of temporal smoothing of CPUE indices on the consistency of projections of SSB.

We use the latest SBT operating model to fit historic data consistent with what was available at CCSBT data exchanges between 2008 and 2013. The fitted models are then used to make projections under a zero catch scenario to 2035 to examine the consistency of the projections as new data are added. We then repeat this procedure with the base CPUE inputs replaced with indices derived from temporally smoothing the base CPUE inputs and compare the results.

The scientific aerial survey index has also exhibited considerable variability over the period investigated and this analysis provides an opportunity to examine the possible influence of individual values of the aerial survey index on predicted recruitment.

The retrospective study suggests the variability in projections of future SSB resulting from adding an additional year's CPUE data are minimal. Furthermore temporal smoothing of the CPUE had negligible effect on these projections. In terms of posterior grid weightings, the smoothed CPUE led to a slightly higher preference for lower steepness and for higher M_{10}, but the net effect of differences in posterior grid sampling on projections of spawning stock biomass appears to be almost zero.

The comparison of retrospectively projected aerial survey index with realised aerial survey index suggest the uncertainty in future aerial survey index levels predicted by the model appear about right. Whilst interannual variations in projected future SSB are quite small, it appears that the differences that are observed are likely to be mostly influenced by the inclusion of new values of the aerial survey index.

1 Introduction

The possibility of temporal smoothing of modelled CPUE indices, previously discussed in Laslett (2001), was explored at the 2012 meeting of the Extended Scientific Committee of the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) (Chambers, 2012). At the same time there has been a perception that projections of future spawning stock biomass (SSB) of southern bluefin tuna have been excessively variable from one year to the next. For instance, it was noted at the 2009 meeting of the Extended Scientific Committee (ESC) that there was a very low probability of achieving short term reference points aimed at reducing the risk of further decline in SSB at most levels of constant catch projections considered (Anon. 2009). By contrast, at the 2011 meeting of the ESC, it was noted that conditioning of the operating model favoured higher values of steepness and projections were more optimistic than was previously the case (Anon. 2011).

The purpose of this study was to examine the effect of temporal smoothing of the SBT CPUE indices on the variability of projections of future spawning stock biomass. This is done using retrospective analysis to assess the potential for improving the consistency of projections of SSB by replacing the current CPUE data inputs with smoothed equivalents.

The retrospective analyses also provide an opportunity to investigate the influence of the variability in the scientific aerial survey index on predicted recruitment.

2 Method

Six **Base** data files were created suitable for conditioning the current SBT operating model (sbtmod25). The data files were created from the 2013 CCSBT data exchange to be consistent with data that would have been available at CCSBT data exchanges from 2008, 2009, 2010, 2011, 2012 and 2013. The files for 2008 to 2012 were made by deleting the more recent years' data from the 2013 file as appropriate.

Historic w0.5 and w0.8 CPUE indices supplied under the CCSBT data exchange between 2008 and 2013 were then substituted for the 2013 CPUE series in each data file. Both series were replaced in entirety each time because each time the CPUE model is fitted to updated data, historic index values vary slightly due to changes in GLM regression coefficients and normalisation of the index. Historic aerial survey index values also tend to change over time due to updated regression coefficients, but truncated series from the 2013 were used for earlier years rather than previously submitted aerial survey indices because the scaling of the aerial survey data was changed in 2010. The availability assumed for various data types by data exchange year are summarised in Table 1.

Table 1: Last year of availability of operating model data inputs for each CCSBT data exchange year used in the investigation.

Data Exchange Year	Total Catch by Fishery[a]	Length Frequency[a]	Age Frequency[a]	CPUE[b]	Aerial Survey[a]	Troll Survey[a]
2008	2007	2007	2007	2007	2008	2008
2009	2008	2008	2008	2008	2009	2009
2010	2009	2009	2009	2009	2010	2010
2011	2010	2010	2010	2010	2011	2011
2012	2011	2011	2011	2011	2012	2012
2013	2012	2012	2012	2012	2013	2013

[a] Truncated from 2013 CCSBT data exchange. [b] replaced by series from corresponding CCSBT data exchange.

For each of the six data exchange years considered (Table 1) two data files were created.

1) A **Base** data file that included the standard data including the w0.5 and w0.8 CPUE indices as submitted to the CCSBT data exchange between 2008 and 2013

2) A **Smoothed** data file identical to the Base data file except that the w0.5 and w0.8 CPUE indices were temporally smoothed and replaced by their smoothed equivalents.

The latest version of the conditioning code (sbtmod25.exe) was used to fit the operating model to each data set. The current base grid structure (Table 2) was used in each case.

Table 2: The base grid of the operating model parameters used.

Parameter	Values (Prior Weighting)	Fixed/Free
Steepness	0.55 (0.2), 0.64 (0.2), 0.73 (0.2), 0.82 (0.2), 0.9 (0.2)	Free
M_0	0.3 (0.25), 0.35 (0.25), 0.4 (0.25), 0.45 (0.25)	Free
M_{10}	0.07 (0.25), 0.10 (0.25), 0.13 (0.25), 0.16 (0.25)	Free
Omega	1 (1)	Fixed
CPUE Series	w0.5 (0.5), w0.8 (0.5)	Fixed
Ages represented by CPUE	4 - 18 (0.67), 8 - 12 (0.33)	Fixed

After the operating model was fitted to each data file, the resulting posterior grid was used to project spawning stock biomass to 2035 using the latest projection code (sbtprojv119.exe). The predetermined total allowable catch (TAC) was specified up to and including 2012 so that total annual catch in each fishery each year was consistent for all runs. For consistency in total removals in projections between years, reported catch up to 2012 was used for to set future TACs for projections conditioned to earlier data. Beginning in 2013 zero catch was assumed for all runs. Total allocated catch for each fishery was as shown in Table 3.

Table 3: Fishery specific total allocated catch (tonnes) for projections.

Projection Year	LL1	LL2	LL5	Surf. Fishery	Total
2008	4479	909	742	5211	11341
2009	4493	914	1023	5017	11447
2010	3785	1216	564	3942	9507
2011	3761	517	694	3786	8758
2012	4250	472	662	4570	9954
2013-2035	0	0	0	0	0

Projection output produced using the posterior grids fitted to the 12 data files were then compared. The zero catch scenario is not considered realistic, but allows for consistent comparison between the 12 different projection runs and was computationally less demanding than applying the SBT management procedure in each case.

Smoothing of CPUE indices

The w0.5 and w0.8 CPUE indices submitted to the CCSBT were used each year as CPUE inputs into the corresponding year's conditioning model under the **Base** case. To produce the **Smoothed** indices these same data were smoothed using mixed model splines (Wand, 2003) and the conditioning models refitted. The smoothed and unsmoothed CPUE indices used are plotted in Appendix A.

3 Results

Estimates of depletion in 2013, B_{2013}/B_0, from the 12 data files fitted are compared in Figure 1. For the six **Base** data files that were compared, means of B_{2013}/B_0 estimates ranged from approximately 5.1 percent in 2013 to approximately 6.8 percent in 2010. For the six **Smoothed** data files compared, means of B_{2013}/B_0 estimates ranged from approximately 6.2 percent in 2013 to approximately 7.8 percent in 2010.

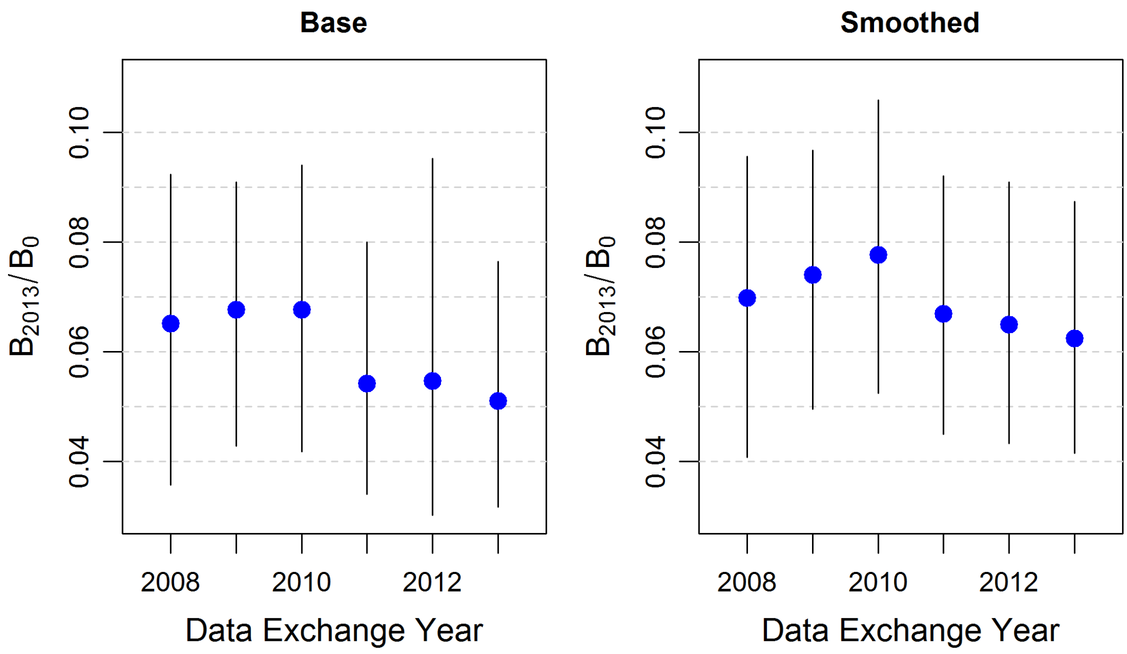

Figure 1: Projected depletion in 2013 with data available at 2008, 2009, 2010, 2011, 2012 and 2013 CCSBT data exchanges for unsmoothed (left panel) and smoothed CPUE (right panel). Dots are the mean estimates; vertical bars are 95 percent confidence intervals.

Using the hypothetical zero catch scenario, estimates of projected depletion in 2035, B_{2035}/B_0, from the 12 data files fitted are compared in Figure 2. For the six **Base** data files that were compared, means of B_{2035}/B_0 estimates ranged from approximately 48 percent in 2009 to approximately 61 percent in 2011. For the six **Smoothed** data files compared, means of projected B_{2035}/B_0 estimates ranged from approximately 49 percent in 2009 to approximately 61 percent in 2011.

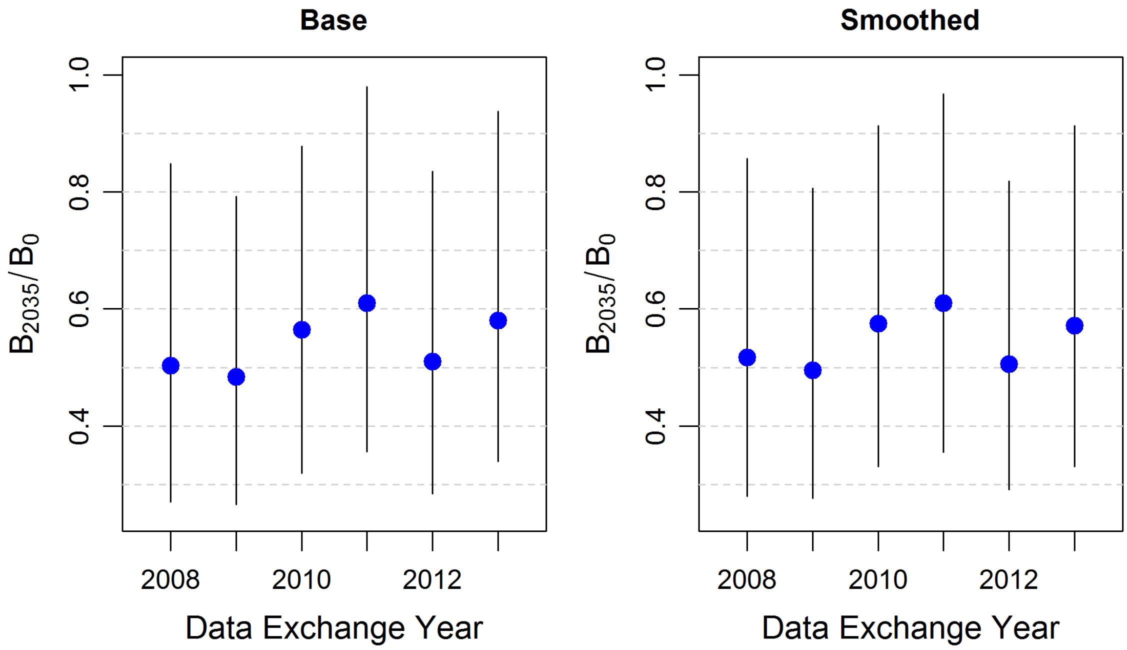

Figure 2: Projected depletion in 2035 under a zero catch scenario from 2013 with data as provided up to 2008, 2009, 2010, 2011, 2012 and 2013 for unsmoothed (left panel) and smoothed CPUE (right panel). Dots are the mean estimates; vertical bars are 95 percent confidence intervals.

Figure 3 shows the progression of predicted aerial survey index with the addition of new data compared with the observed aerial survey index submitted to the CCSBT data exchange in 2013. All of the projections shown in Figure 3 are as given by the operating model fit to that year's data file without any smoothing of CPUE indices.

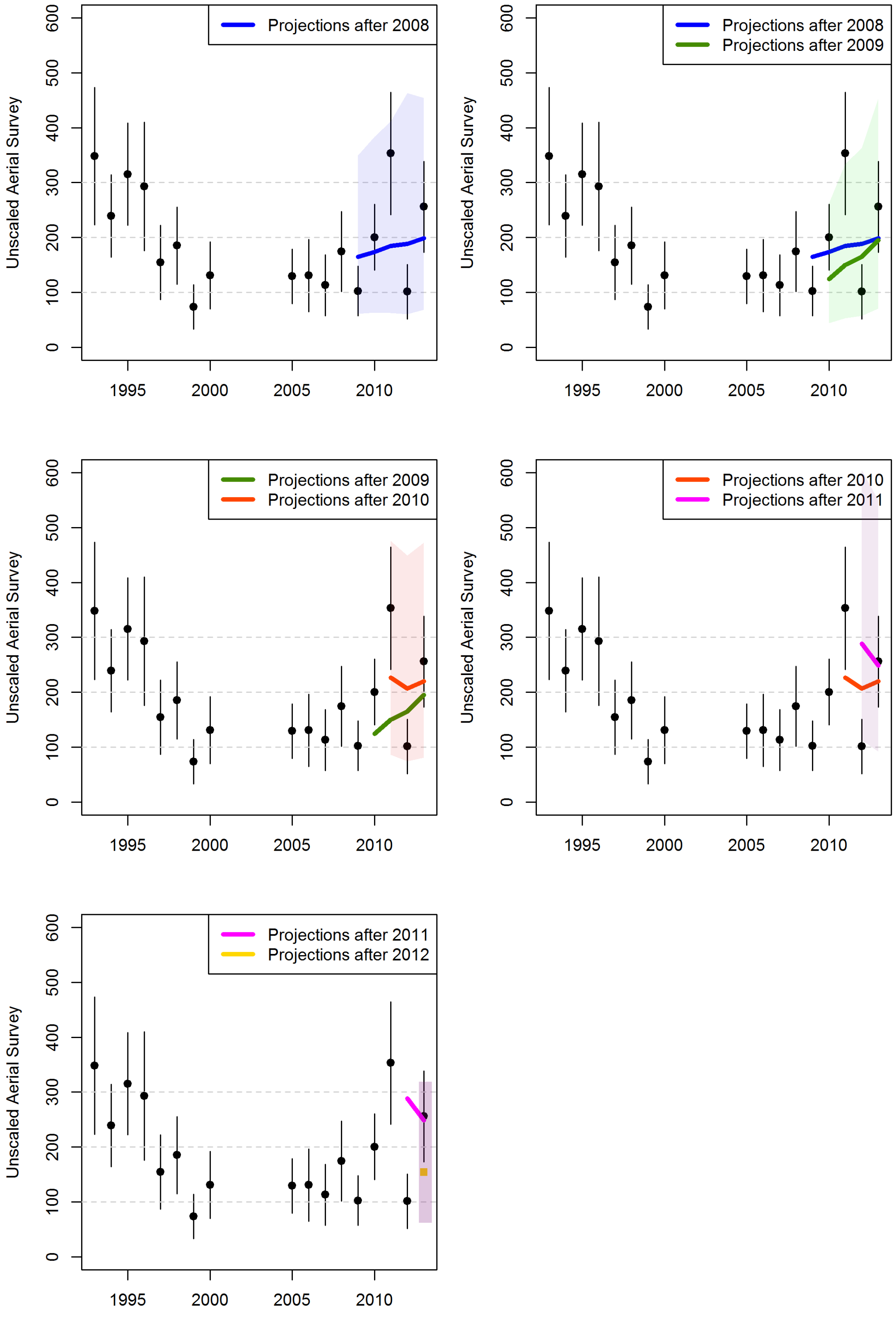

Figure 3: Comparison of realised and projected Aerial Survey Index showing means and 95 percent confidence intervals. Predictions are based on model fits to datasets with unsmoothed CPUE in all cases.

Figure 4 shows estimates of recruitment for SBT cohorts from 2007 to 2015 that result from fitting the operating model to data from the CCSBT data exchange between 2008 and 2013. The estimates shown in Figure 4 are derived from **Base** case data files each year with no smoothing of CPUE.

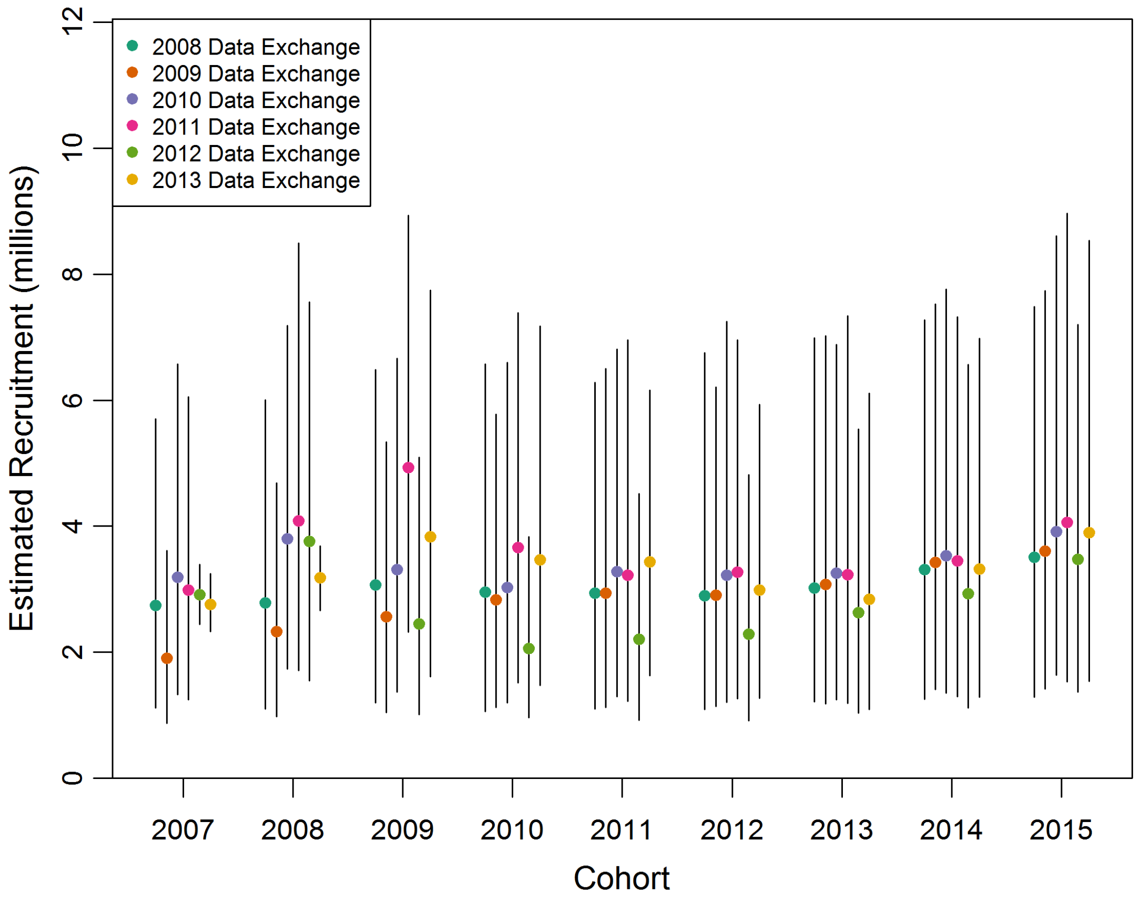

Figure 4 Estimated and projected recruitment for cohorts between 2007 and 2015. Estimates are given for each cohort from operating model fits to data from 2008, 2009, 2010, 2011, 2012 and 2013 CCSBT data exchanges. Predictions are based on model fits to datasets with unsmoothed CPUE in all cases.

4 Discussion

Estimates of current relative spawning stock biomass, B_{2013}/B_0 made with data incorporating the smoothed CPUE series tend to be slightly higher than those made with data incorporating the unsmoothed w0.5 and w0.8 indices (Figure 1). The differences are quite small, but increase slightly from models fitted from the 2010 data exchange onwards. This can be partly explained by comparing the smoothed and unsmoothed CPUE series shown in Figures 5 and 6. Referring particularly to the 2006 and 2007 CPUE index values, we see that the fitted spline is not very different to these historically low CPUE values when the CPUE data finish in 2007. However, after markedly higher CPUE is observed in 2008 and particularly in 2009, the fitted spline moves increasingly away from the very low CPUE values observed in 2006 and 2007. The difference in B_{2013}/B_0 estimated with smoothed CPUE as opposed to unsmoothed CPUE becomes greater as the fitted CPUE splines moves further away from the 2006 and 2007 index values.

There is clearly some year-to-year variation in projected relative spawning stock biomass in 2035, B_{2035}/B_0 (Figure 2). However, this variation is not extreme compared with the predicted within-year uncertainty, and, perhaps surprisingly, the corresponding estimates of projected spawning stock biomass made with the smoothed CPUE are virtually the same as those resulting from the unsmoothed CPUE. That is, the analysis here provides no evidence that smoothing CPUE is likely to result in more consistent projections of spawning stock biomass.

When fitted to smoothed CPUE, the operating model appears to have a slightly higher preference for the lower steepness values and the higher values of M_{10} on the grid when compared with the unsmoothed CPUE series (Appendix B). It would appear, however, that the net effect on projections is negligible.

It might be the case that the variations in projected spawning stock biomass shown in Figure 2 are actually driven primarily by deviations of the observed aerial survey index each year from its predicted value given data up to the previous year. Figure 3 shows the progression of operating model projections of aerial survey index against the aerial survey series submitted as part of the CCSBT data exchange in 2013. A couple of points can be gleaned from Figure 3.

1) The variability in future aerial survey index values, as indicated by the shaded 95 percent confidence intervals in Figure 3 appear to be capturing the true variability well.

2) Over the period investigated, the most recent aerial survey index value has not been a very useful predictor of the index value in the next year.

Relating observed deviations from predicted aerial survey index (Figure 3) with changes in, B_{2035}/B_0 (Figure 2) we notice that when a lower than predicted aerial survey index value (Figure 3, top left) is incorporated in 2009, a slight decrease in B_{2035}/B_0 occurs. This is followed by a decrease in the predicted 2010 aerial survey index value (Figure 3, top right). The realised value in 2010 is well above the updated prediction from the 2009 data exchange. This is followed by a moderate increase in predicted B_{2035}/B_0 (Figure 2) when the 2010 data are added. The predicted aerial survey in 2011 is then revised upward (Figure 3, middle left), but the realised index value in 2011 is observed well above even the updated prediction. This is followed by a further upward revision of projected B_{2035}/B_0 (Figure 2) when the 2011 data are added. The 2012 index value is then observed very much below its predicted value (Figure 3, middle right) and projected B_{2035}/B_0 exhibits a moderate decrease when the 2012 data are added. Then most recently, the 2013 aerial survey index is observed comfortably above its prediction based on 2012 data and again projected B_{2035}/B_0 increases when the 2013 data are added.

The effects of updating the data each year on estimates of recruitment for particular cohorts is shown in Figure 4. It can be seen that the 2009 data with the 2009 aerial survey index leads to a decrease in predicted recruitment for the 2007, 2008 and 2009 cohorts. The 20010 data, lead to larger increases in estimates of the same quantities meaning they recover to levels higher than would have been predicted in 2008. The 2011 data, when the highest aerial survey index was observed, lead to a particularly large increase in the estimated size of the 2009 cohort, with a smaller increase in the 2010 cohort. The 2012 data, when a low aerial survey index was observed, lead to a large decrease in 2009 recruitment, but also substantial decreases for cohorts between 2010 and 2013. Finally, after the 2013 data are included, the estimated recruitment between 2010 and 2013 increases once again.

Overall there is some suggestion that the most recent value of the aerial survey is driving the observed variation in projections of B_{2035}/B_0. Investigation of the effect of smoothing the aerial survey index was considered, but the need to also make an appropriate adjustment to the log covariance matrix of the aerial survey meant this was considered prohibitively difficult.

It would not be expected or even appropriate for updates of SSB projections to exhibit no interannual variation. Appending an additional year's data provides the first information on a new recruited age class which is likely to differ in size to some extent from that predicted by the projection model. At the same time new information is received on other age classes. On the other hand, given the number of age classes that comprise the spawning stock of SBT, the change in projections resulting from the addition of a single year's data should be fairly minimal. There may be value in discussing the level of influence of the latest aerial survey index on projected future recruitment. However, current model projections do not appear particularly sensitive to these changes.

Appendix A - Smoothed CPUE Indices

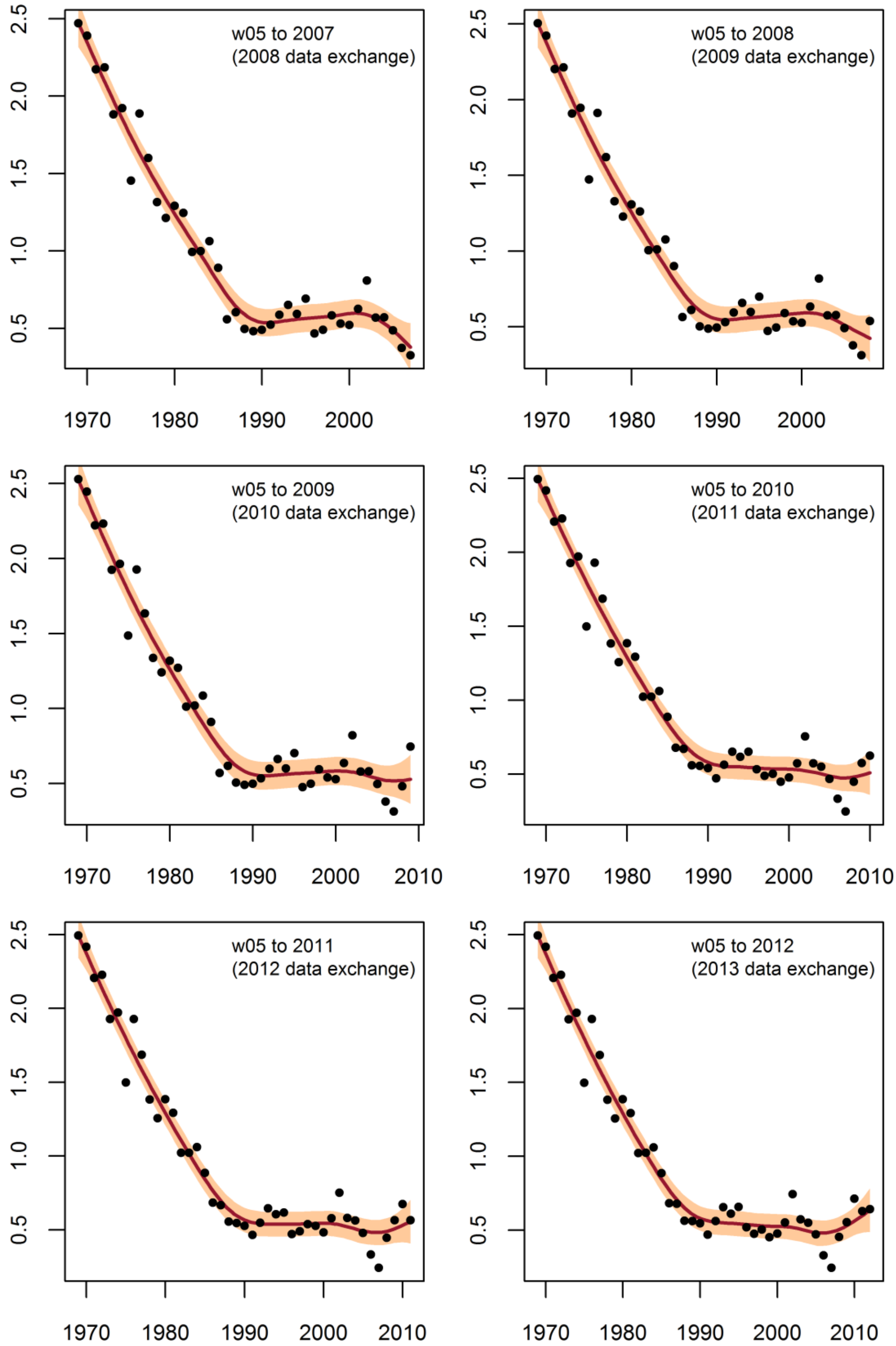

Figure 5: Progression of w05 index with semi-parametric smooth from 2007 (top left) to 2012 (bottom right).

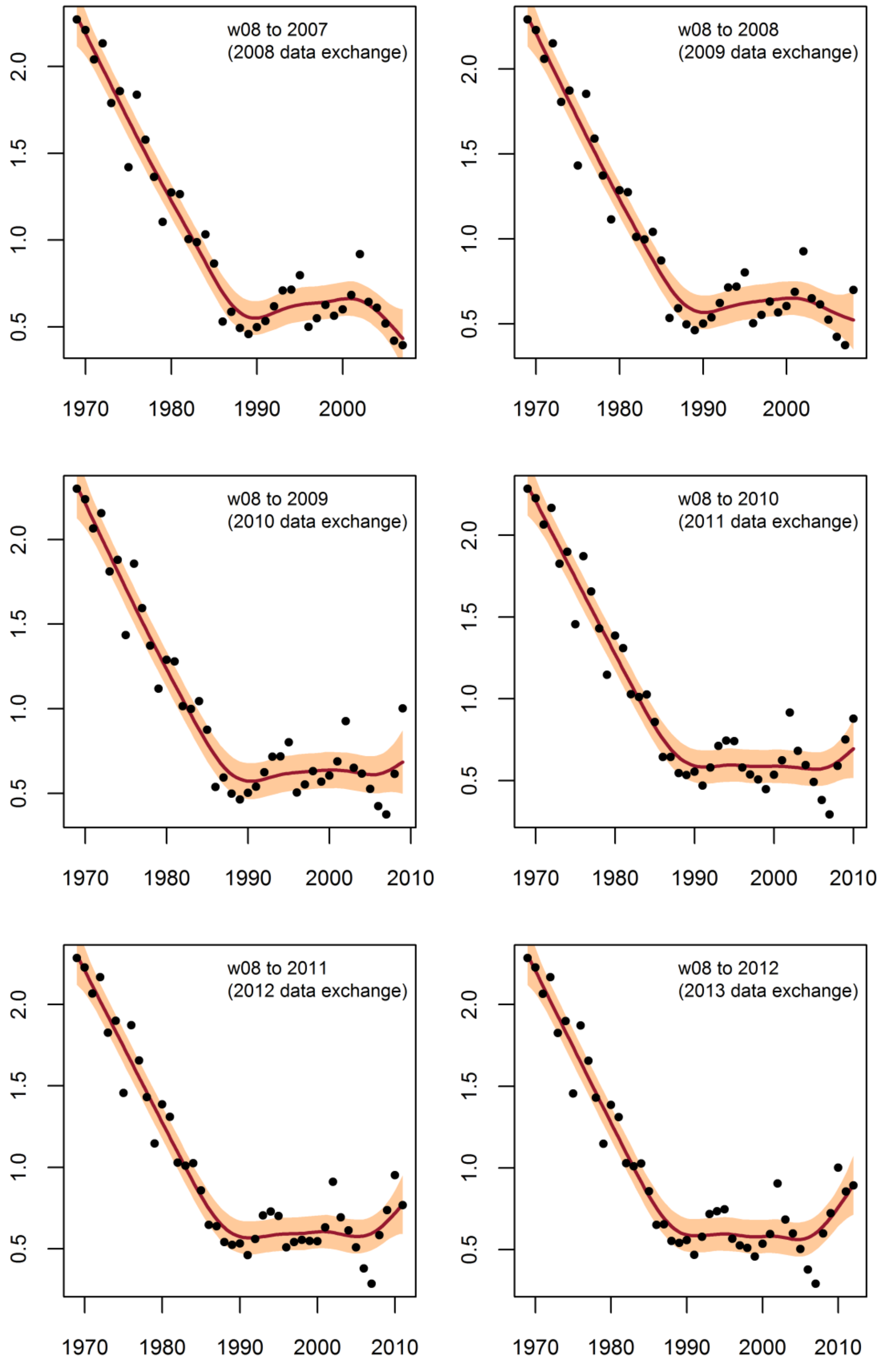

Figure 6: Progression of w08 index with semi-parametric smooth from 2007 (top left) to 2012 (bottom right).

Appendix B - Posterior Grid Structure

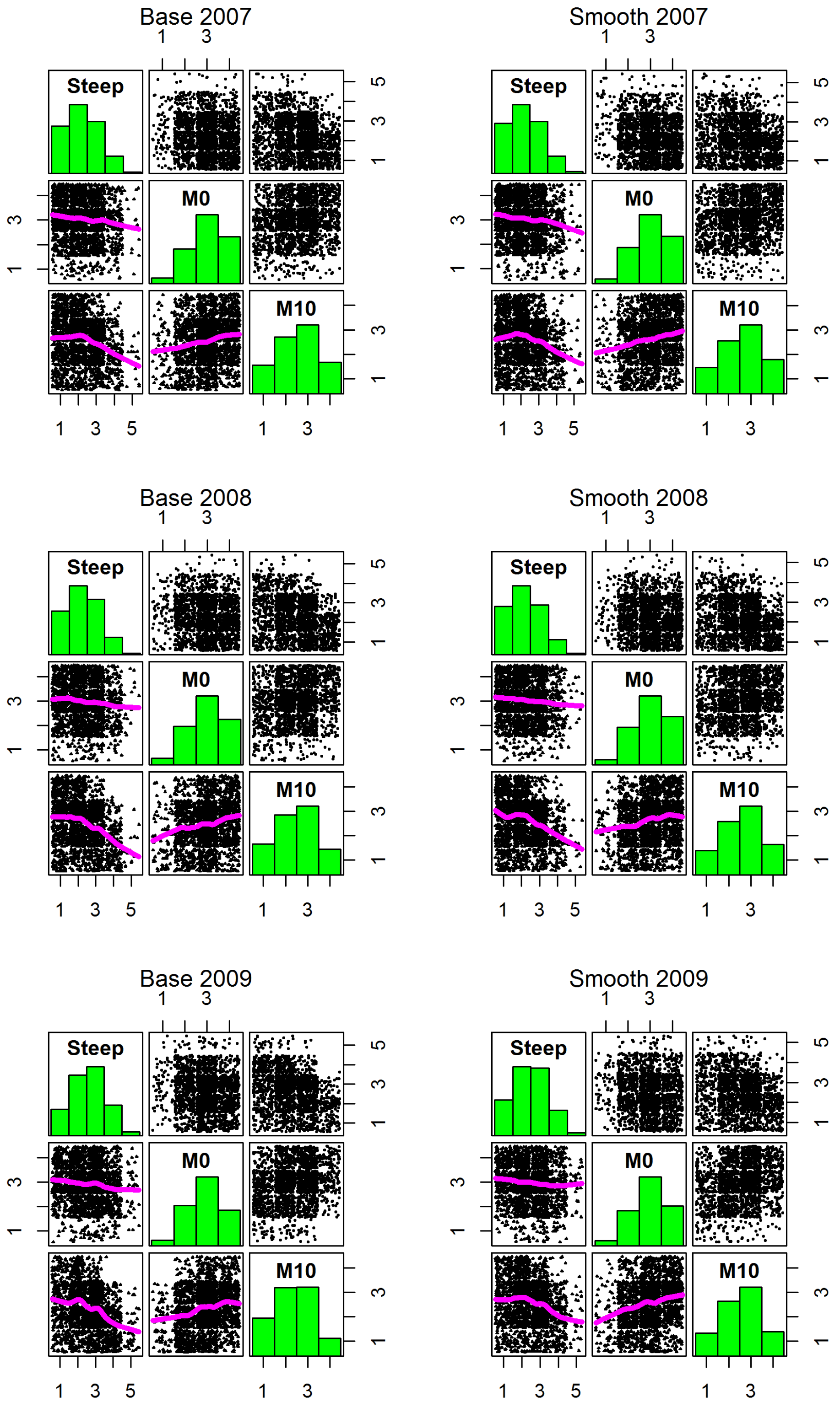

Figure 7: Posterior grid sampling of free parameters given data up to 2007 (top) to 2009 (bottom). The fits using regular CPUE series are shown on the left hand column and with smoothed CPUE on the right column.

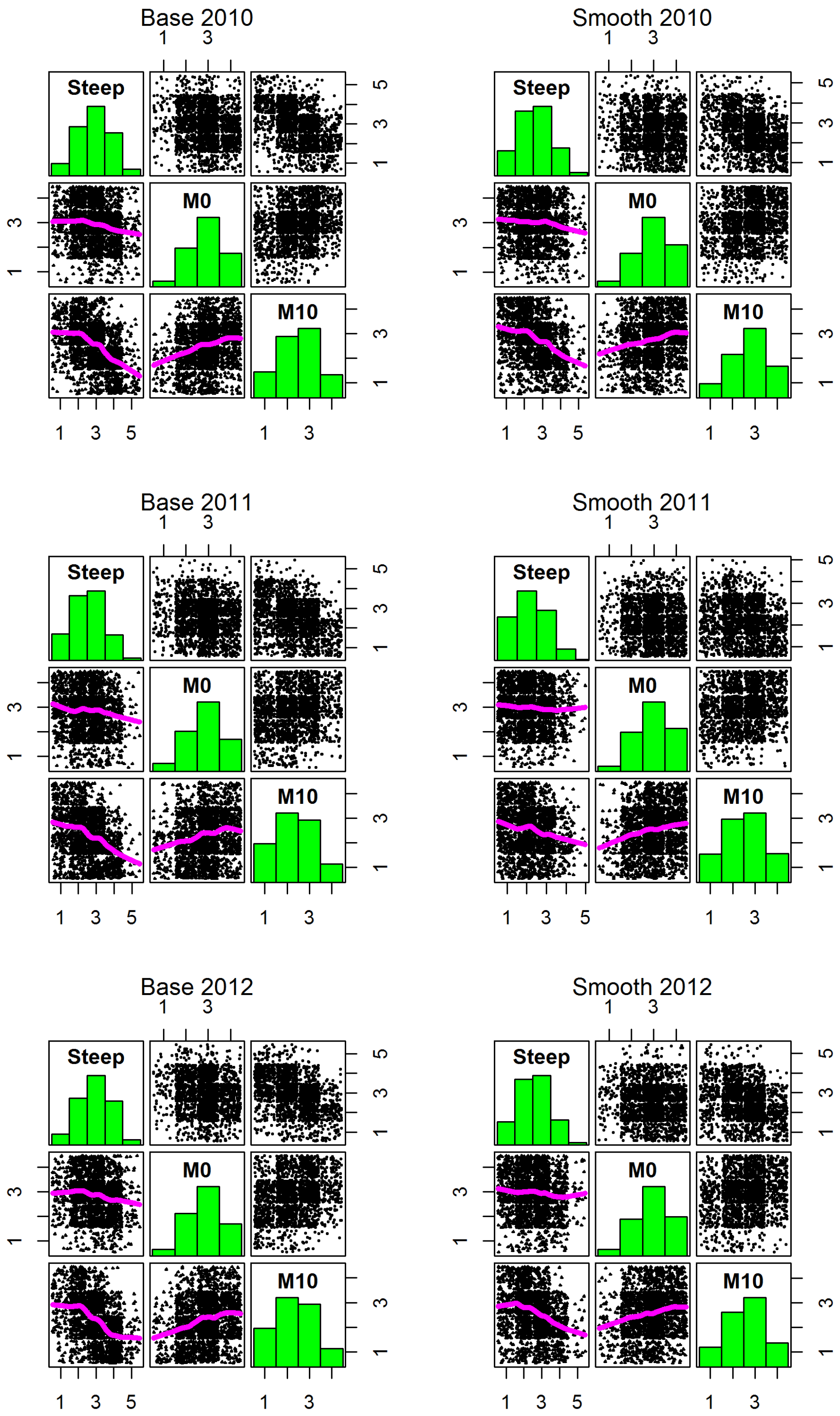

Figure 8: Posterior grid weightings of free parameters fitted to data up to 2010 (top), 2011 (middle) and 2012 (bottom). The left hand column shows the fits using the base CPUE series and the right column shows the fits using smoothed CPUE.

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