Proposed Modification to OMP-04 as a Result of the Sardine Population Being Outside the Range Tested

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Cunningham and Butterworth (2006a) indicated a need to modify the rule for directed sardine TAC in OMP-04 as a precautionary measure in case a low biomass be observed in November 2006, resulting in the current OMP setting a TAC corresponding to an inappropriately high harvest proportion. This modification to the rule is necessary due to the below average recruitment to the sardine population in 2004 and 2005, which has resulted in the population being outside the range projected when OMP-04 was tested.

Directed Sardine TAC Rule

OMP-04 currently calculates directed sardine TAC as follows:

Directed sardine TAC: $TAC_y^S = \beta \, B_{y-1,Nov}^S$ (1)

subject to:

$$\begin{array}{ll} \max\left\{\left(1-c_{mxdn}^S\right)TAC_{y-1}^S\,;\,c_{mntac}^S\right\} \le TAC_y^S \le c_{mxtac}^S & TAC_{y-1}^S \le c_{tier}^S \\ \left(1-c_{mxdn}^S\right)c_{tier}^S \le TAC_y^S \le c_{mxtac}^S & TAC_{y-1}^S > c_{tier}^S \end{array} \quad (2)$$

where:

$\beta = 0.14657$	- a control parameter reflecting the proportion of the previous year's November spawner biomass index of abundance that is used to set the directed sardine TAC.
$B_{y,Nov}^S$	- the observed estimate of sardine abundance (in thousands of tons) from the hydroacoustic spawner biomass survey in November of year y.
$c_{mxdn}^S = 0.15$	- the maximum proportional amount by which the directed sardine TAC can be reduced from one year to the next.
$c_{mntac}^S = 90\,000t$	- the minimum directed TAC that may be set for sardine.
$c_{mxtac}^S = 500\,000t$	- the maximum directed TAC that may be set for sardine.
$c_{tier}^S = 240\,000t$	-2-tier break for directed sardine TAC

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Exceptional Circumstances for the directed sardine TAC apply if $B^S_{y-1,Nov} < 250\,000\text{t}$, in which case the TAC under Exceptional Circumstances is calculated as follows:

$$TAC^S_y = TAC^{S*}_y \left(\frac{B^S_{y-1,Nov}}{250} \right)^2 \tag{3}$$

where TAC^{S*}_y is calculated using equation (1) and constraints (2).

Proposed Modification to the Rule

As suggested by Cunningham and Butterworth (2006a), a linear transformation from the TAC rule with the constraint of a 15% interannual decrease in directed sardine TAC (as currently for OMP-04) and the one without was tested. The proposed modification to the rule for directed sardine TAC was thus:

Directed sardine TAC: $TAC^S_y = \beta\, B^S_{y-1,Nov}$ (4)

subject to:

$$\max\left\{ \left(1-c^S_{mxdn}\right) TAC^S_{y-1} \times \frac{B^S_{y-1,Nov}-250}{B^*-250} + TAC^{S*}_y \frac{B^*-B^S_{y-1,Nov}}{B^*-250} ; c^S_{mntac} \right\} \le TAC^S_y \le c^S_{mxtac} \qquad TAC^S_{y-1} \le c^S_{tier},\ B^S_{y-1,Nov} \le B^*$$

$$\max\left\{ \left(1-c^S_{mxdn}\right) TAC^S_{y-1} ; c^S_{mntac} \right\} \le TAC^S_y \le c^S_{mxtac} \qquad TAC^S_{y-1} \le c^S_{tier},\ B^S_{y-1,Nov} > B^*$$

$$\left(1-c^S_{mxdn}\right) c^S_{tier} \le TAC^S_y \le c^S_{mxtac} \qquad TAC^S_{y-1} > c^S_{tier}$$

where $TAC^{S*}_y = \max\left\{ \beta\, B^S_{y-1,Nov} \times 1000 ; c^S_{mntac} \right\}$ (5)

This proposed modification to the rule for directed sardine was tested for a range of B^* values from 400 to 1000 (in thousands of tons), and the effect of this range on the directed sardine TAC for 2007 is shown in Figure 1a (upper panel) and Figure 1b.

Testing the Modified Rule

The assessment sensitivity test of Cunningham and Butterworth (2006b) was used as a conservative baseline hypothesis, H_0, to define starting values of numbers-at-age at the beginning of 2007 for projections (note that this sensitivity is more conservative than the base case assessment of that paper, giving greater weight to fitting recent low recruitment survey results). Furthermore, for H_0 the stock-recruitment relation used for projections has deliberately been conservatively chosen by treating the three highest model predicted recent sardine recruitments (as sampled by the May recruitment surveys for the years of 2000 to 2002) as “anomalies”, and ignoring them in a fit of a hockey-stick relationship to the assessment’s spawning biomass and recruitment estimates (see Figure 2). This fit also provided the estimate for the variance of recruitment about this curve, with auto-correlation ignored for the purposes of this exercise.

Given concerns arising from the fact that sardine of 4- and 5-years-of-age by November 2006 were estimated in Cunningham and Butterworth (2006b) to be likely to contribute about two-thirds to the biomass at that time, and that this biomass estimate could be positively biased as a result, perhaps, of setting natural mortality *M* for older ages too low, two alternative hypotheses were considered which decrease the biomass of 2+ sardine in November 2006:

H_{lowB}: the sardine numbers-at-age (and biomass) in November 2005 were decreased by a factor of one-third from H_0.

H_{lowerB}: the sardine numbers-at-age (and biomass) in November 2005 were decreased by a factor of two-thirds from H_0.

In addition, a further alternative hypothesis, H_{SR}, was considered in which the three highest model predicted recent sardine recruitments were included in the fit of a hockey-stick relationship to the assessment's estimates (see Figure 2).

The distribution of assessment model predicted and possible observed sardine biomass in November 2006 under H_0 is given in Figure 3. Further details of the testing process applied for this rule are given in the Appendix.

Results

Figure 4 shows the median, 5- and 10-percentile of the model predicted (true) sardine biomass trajectories for the four alternative hypotheses under alternative choices for B^*, while Figure 5 shows the median and 20-percentile of the 10% of trajectories resulting in the lowest biomasses over the 2006-2025 projection period. (In all cases the same set of 50 trajectories were used for these comparisons, based on the set of trajectories that reached the lowest biomass over the projection period for a low value of B^*).

The case with $B^* = 400$ results in very low 5-percentile trajectories under H_{lowerB}. In addition, the apparent (i.e. in relation to the observed as distinct from the true) harvest proportion in 2007 for $B^* = 400$ increases above 0.35, the maximum reached under OMP-04 in the absence of the constraint on the interannual decrease in sardine TAC (Figure 1). On the other hand, the apparent harvest proportion in 2007 for $B^* = 600$, 800 or 1 000 remains below 0.35. For these reasons it is suggested the B^* value chosen should be > 400.

The modified OMP would respond to a decrease in the sardine biomass more quickly for higher B* values, decreasing the directed sardine TAC earlier and/or to a greater extent than for lower B* values. Thus the biomass trajectories for higher B* values do not decrease as far as those for lower B* values in the short- to medium-term. The result of a change in B^* can be seen most effectively when comparing the worse case scenario of H_{lowerB} (Figures 4 and 5, right hand panel). In all cases the effect of a change in B^* is greater in the short term (given the current state of the sardine stock) compared to the long term, with a decrease in the average catch with increasing B^* over the short term (Figure 6). The long-term effect of a change in B* is less noticeable. In fact, the predicted state of the sardine stock in 2025 is similar for all B^* options (Figures 6-8; see appendix for detailed results for $B^* = 600$).

The individual biomass trajectories for the 50 simulations that result in the lowest biomass during the 2006-2025 projection period are plotted in Figure 9 for H_{lowB}. It is worth noting that in only two cases (Figures 9b and 9d) is a virtually irrecoverable situation predicted within the next 2-3 years.

The risk to the sardine resource (defined as the probability that adult sardine biomass falls below the average adult sardine biomass over November 1991 and November 1994 at least once during the projection period) is 0.42 over the short term, and 0.61 over the long term, under H_0. This is considerably higher than the 0.1 to which OMP-04 was initially tuned, but is a direct result of i) the low state of the stock as estimated in November 2005 and ii) the more conservative H_0 selected for testing this modification to OMP-04 compared to the base case assessment of Cunningham and Butterworth (2006b). As expected, this risk decreases for the more optimistic hypothesis of H_{SR} and increases for the more pessimistic hypotheses of H_{lowB} and H_{lowerB} (Table A1).

Recommendation

As already mentioned above, a choice of B^* = 400 could still result in a very low sardine biomass occurring, and a consequent harvest proportion > 0.35. On the other hand, the average catch in the short term decreases with increasing B^*. In order to avoid this loss of catch, the trade-off choice suggested is to adopt B^* = 600 for the modified directed sardine TAC rule in OMP-04 (equations (4) and (5)). Even though this choice results in some not entirely satisfactory projection results in some of the plots of this paper, the high degree of conservatism built into most of the scenarios considered here should be borne in mind.

References

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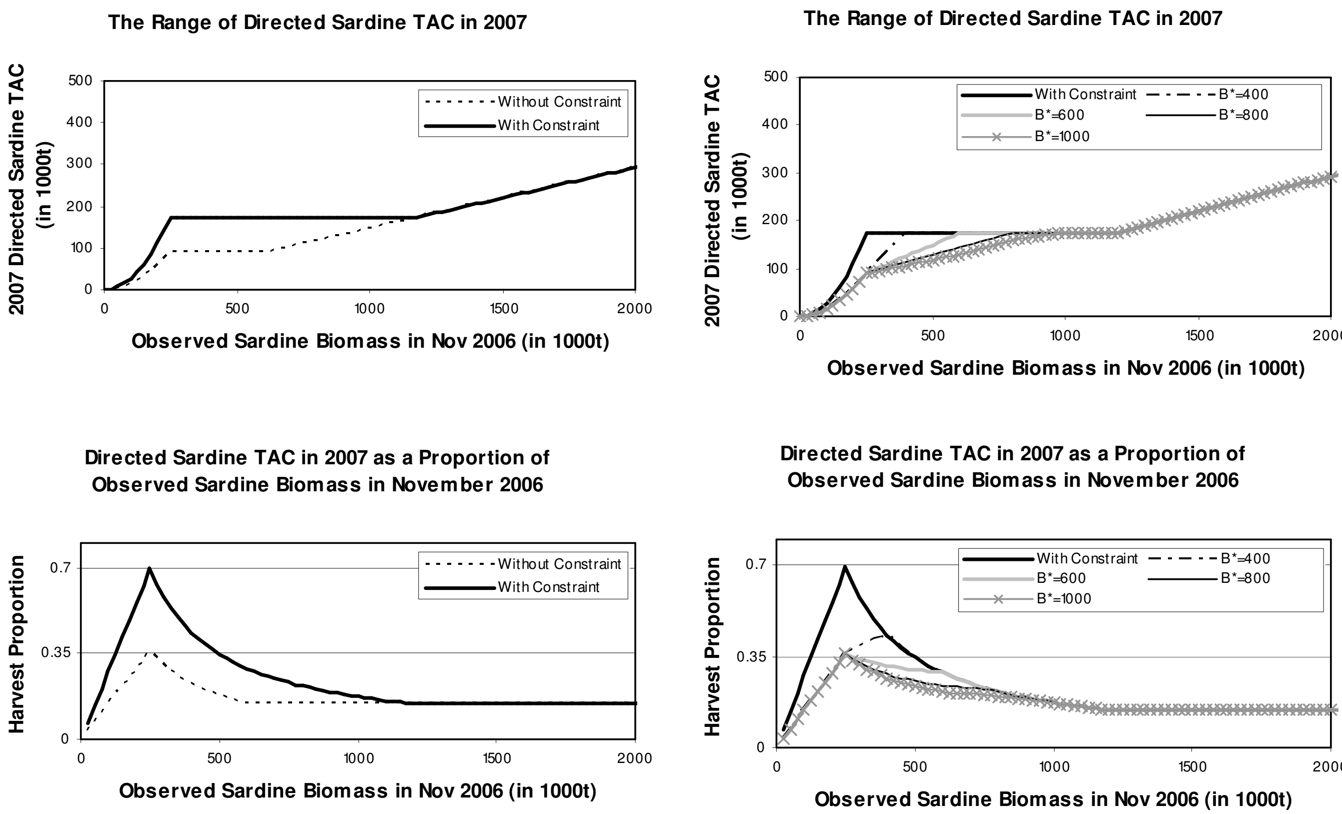

Figure 1a. The directed sardine TAC in 2007 under OMP-04 with and without the constraint of a maximum interannual decrease of 15% plotted as a function of possible observed sardine biomass in November 2006. The directed sardine TAC in 2007 under the proposed modification to the directed sardine TAC rule is also plotted for a combination of B values. The lower panel shows the directed sardine TAC in 2007 as a proportion of possible observed sardine biomass in November 2006 (i.e. the harvest proportion), plotted as a function of the latter.*

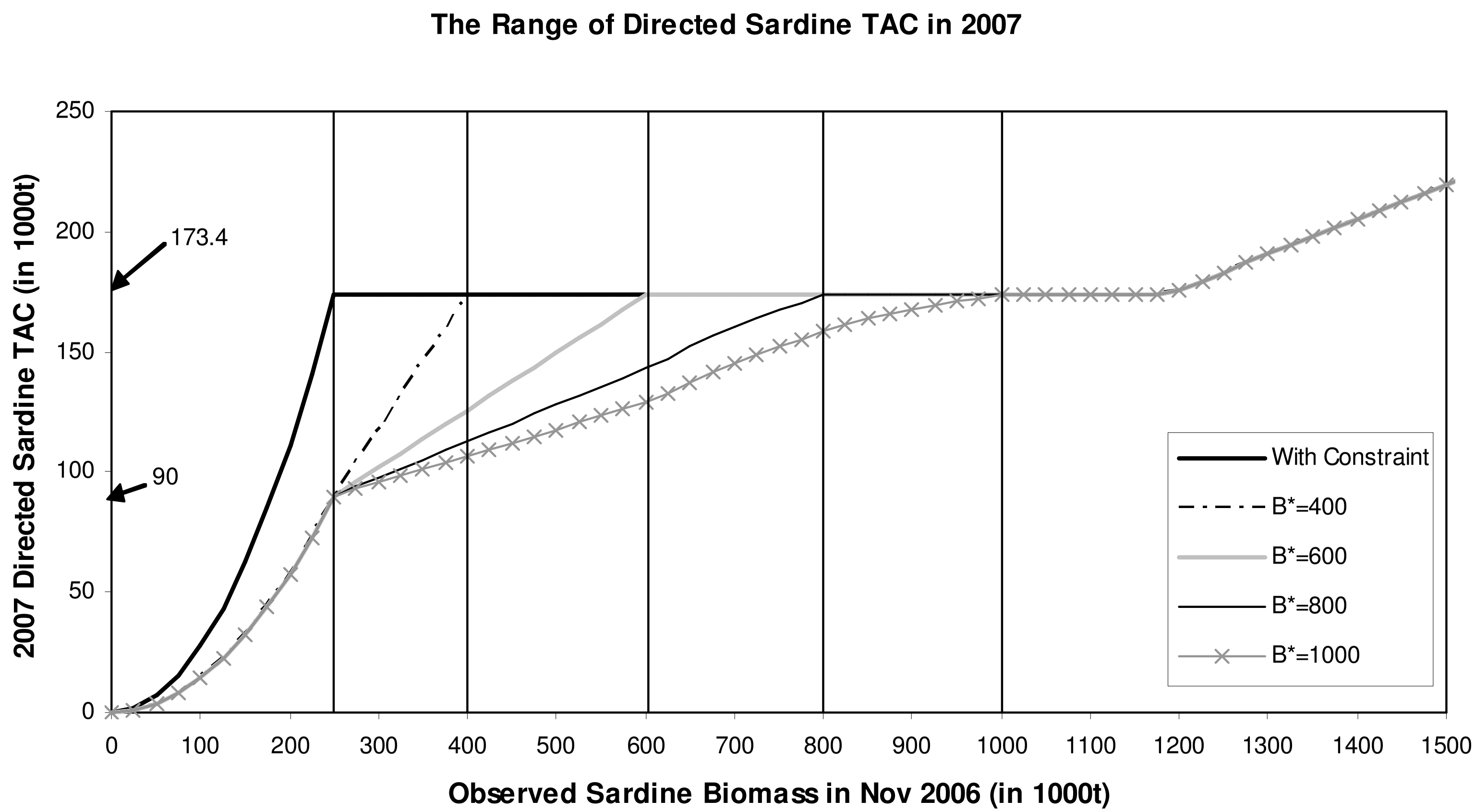

Figure 1b. The directed sardine TAC in 2007 under the proposed modification to the directed sardine TAC rule is plotted as a function of possible observed sardine biomass in November 2006 for a combination of B values.*

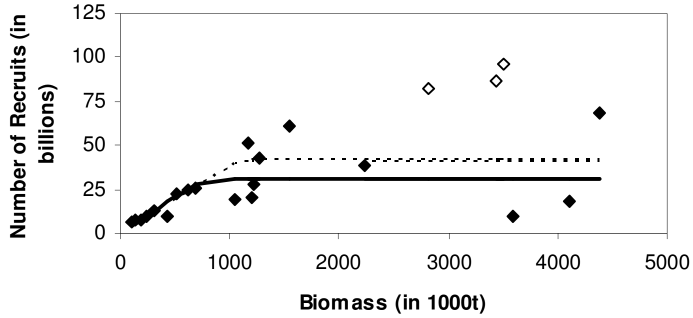

Figure 2. Assessment model predicted sardine biomass and recruitment at the posterior mode (solid diamonds). The hockey-stick model fit to the predicted values at the mode is shown when excluding (solid line) and including (dotted line) the three years of very good recruitment (depicted by open diamonds).

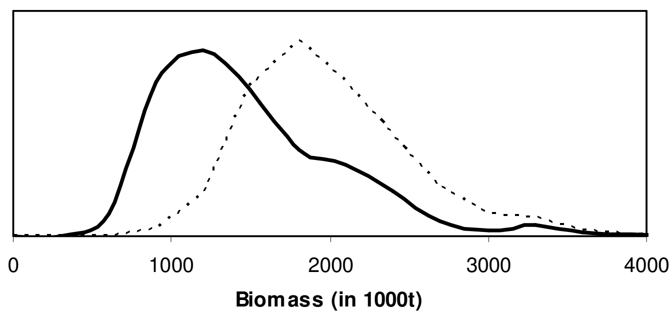

Figure 3. The distribution of assessment model predicted (dotted line) and predicted observed (solid line) sardine biomass in November 2006. The medians of these two distributions differ due to bias in the hydroacoustic estimate and (to a lesser extent) the skew distribution of the log-normal observation error assumed.

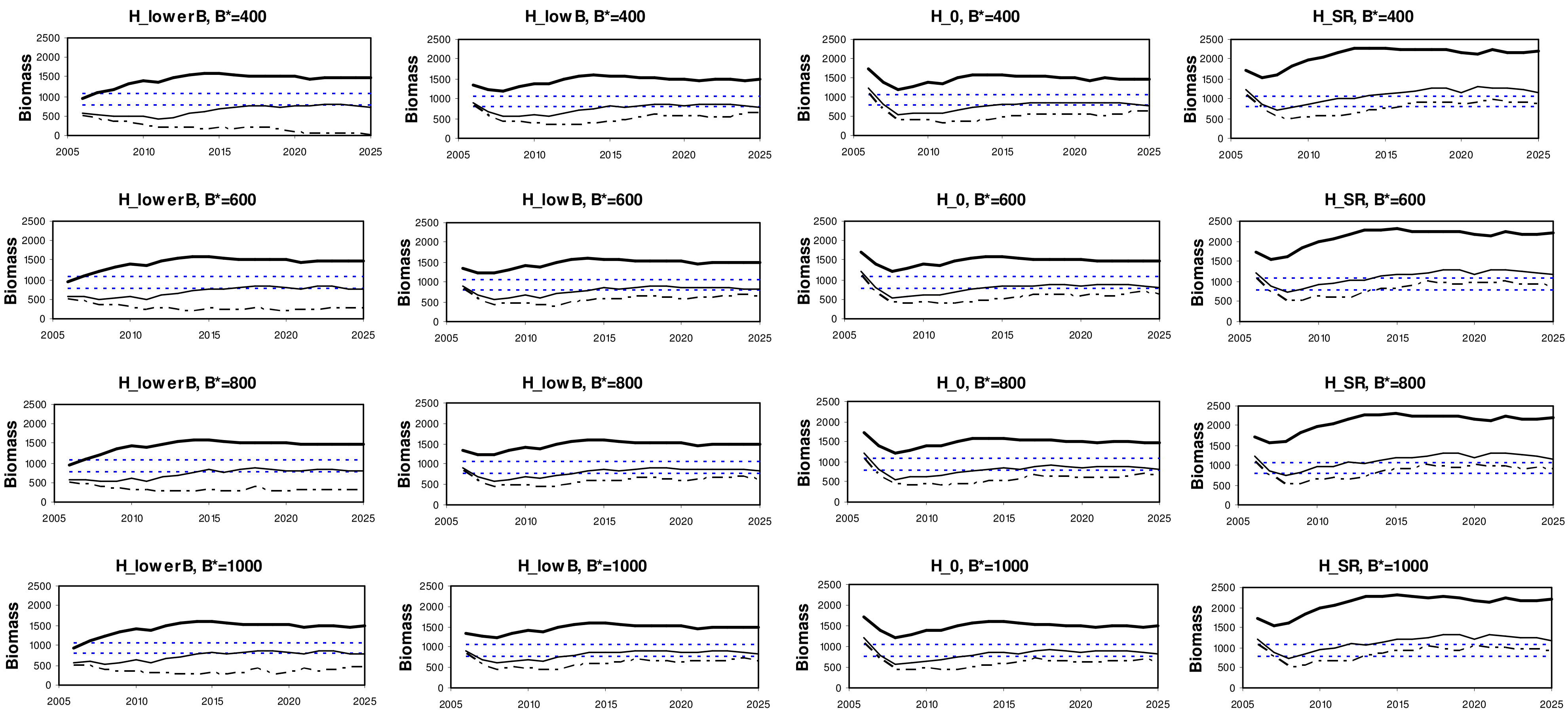

Figure 4. Median (thick solid line), 10%ile (thin solid line) and 5%ile (dashed-dot line) of the model predicted (true) sardine biomass trajectories (in 1000t) for the four hypotheses considered (in columns) under four alternative choices for B (in rows). The 90%ile of the biomass corresponding to the threshold used to define risk is also shown (dotted lines).*

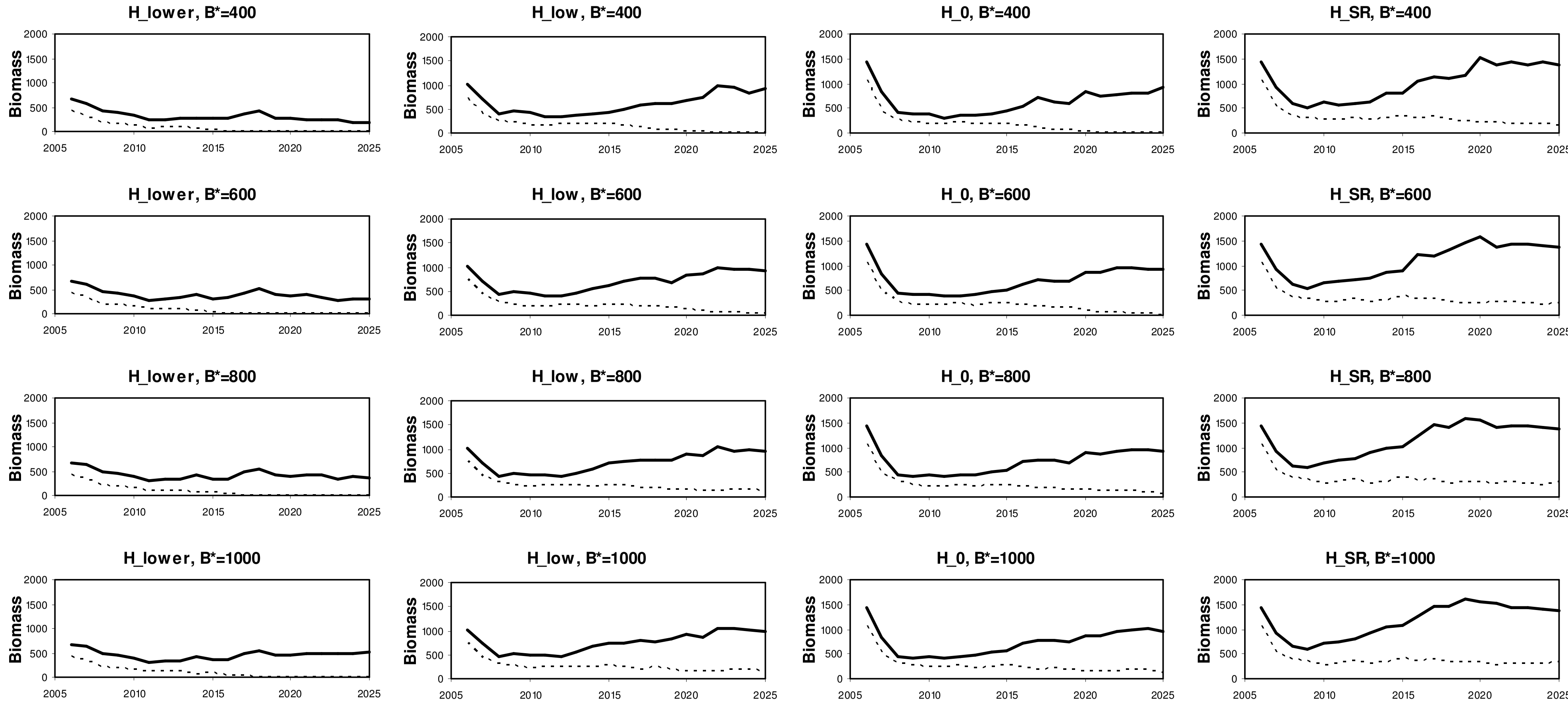

Figure 5. Median (thick solid line) and 20%ile (dotted line) of the lowest 10% of the 2006-2025 model predicted (true) sardine biomass trajectories (in 1000t) for the four hypotheses considered (in columns) under four alternative choices for B (in rows).*

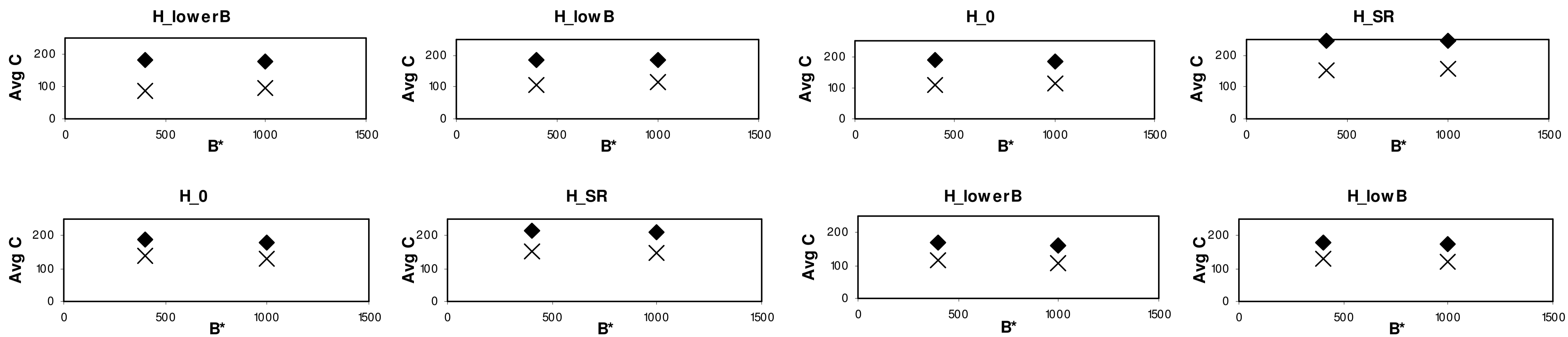

Figure 6. The average catch (in 1000t) for all simulations (solid diamonds) and the lowest 10% of model 2006-2025 predicted biomass trajectories (crosses) under a 6-year projection period (upper panel) and 20-year projection period (lower panel) for the four hypotheses considered (in columns) under B = 400 and 1 000 000t (horizontal axes). Results for intermediate values of B* can be inferred by linear interpolation.*

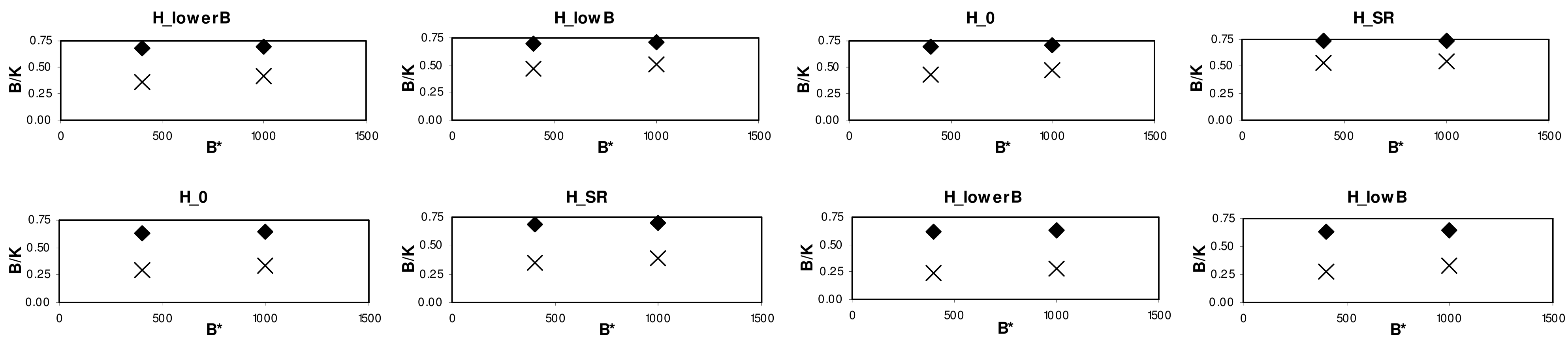

Figure 7. The model predicted (true) sardine biomass, as a proportion of carrying capacity in 2011 (upper panel) and 2025 (lower panel) for the four hypotheses considered (in columns) under B = 400 and 1 000 000t (horizontal axes). Results are shown for all simulations (solid diamonds) and the lowest 10% of 2006-2025 model predicted biomass trajectories (crosses).*

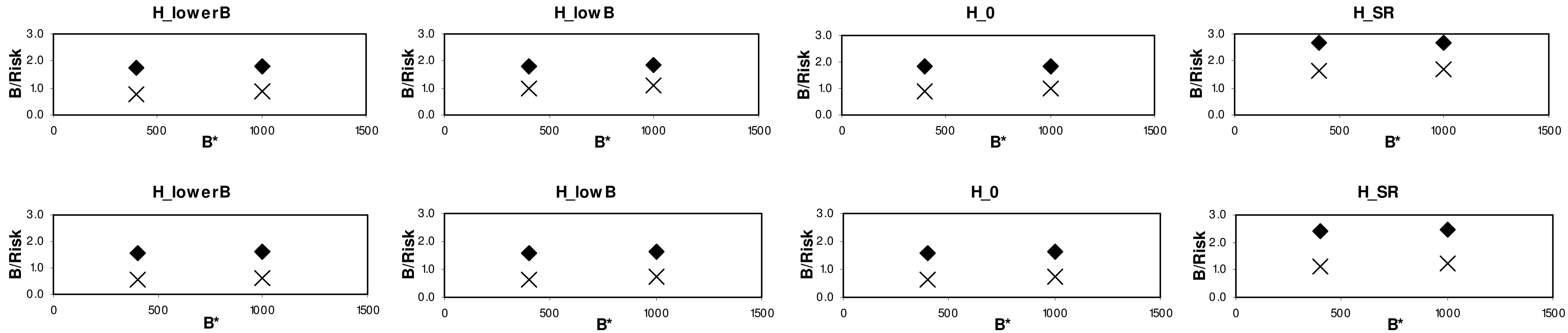

Figure 8. The model predicted (true) sardine biomass, as a proportion of the biomass corresponding to the threshold used to define risk, in 2011 (upper panel) and 2025 (lower panel) for the four hypotheses considered (in columns) under $B^* = 400$ and 1 000 000t (horizontal axes). Results are shown for all simulations (solid diamonds) and the lowest 10% of 2006-2025 model predicted biomass trajectories (crosses).

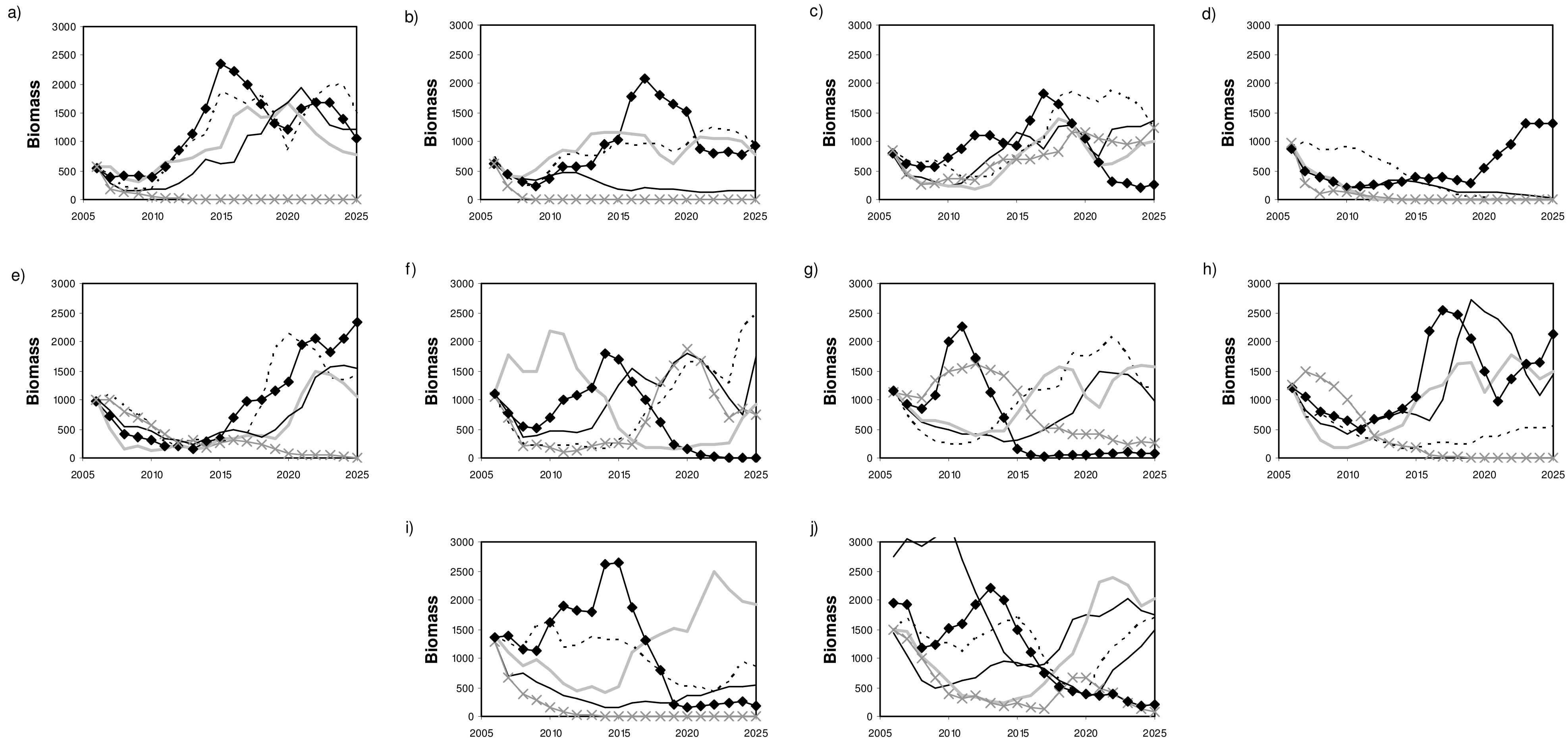

Figure 9. The 50 (lowest 10%) trajectories resulting in the lowest model predicted sardine biomass at some point over the 2006-2025 projection period for H_{lowB} with $B^* = 600$. The range of starting biomass for the plots is a) 544 – 611, b) 620 - 745, c) 776 – 854, d) 870 – 969, e) 972 – 1027, f) 1058 – 1120, g) 1123 – 1190, h) 1193 – 1275, i) 1358 – 1434, and j) 1482 – 2737 thousand tonnes.

Appendix: Further Results

Further Details of the Testing Process for the Modified Rule

MCMC was used to simulate posterior distributions for key model parameters, with the additional variance parameters $(\lambda_N^S)^2$ and $(\lambda_0^S)^2$ fixed at 0.000001 to ease convergence. A chain of 40 000 000 samples was run, beginning at the posterior mode. A burn-in of 150 000 was discarded and the remaining chain was thinned by 1000 to decrease any autocorrelation. 500 samples from the posterior distributions were drawn to be used in testing the modification to OMP-04.

The fishery management system used in this exercise was the same as that originally used to test OMP-04 (Cunningham and Butterworth 2004), with the following changes:

i) The projection period was from November 2005 to November 2011 (short term) and 2025 (long term).

ii) The input data for sardine was taken from the updated sardine assessment (H_0, H_{lowB}, H_{lowerB} or H_{SR}). Thus new numbers-at-age in November 2005, selectivities-at-age and stock-recruitment parameters were used. The correlations and residuals used in the implementation and observation models were updated using new sardine estimates up to November 2003 only (to match the unchanged anchovy data up to November 2003).

iii) Any updated data (such as survey observations, observed bycatch ratios, the start date of the 2006 recruit survey, juvenile catch prior to the recruit survey and sardine catch-at-age and anchovy catch-at-age 1 for 2006) were taken as reported/assumed in Cunningham and Butterworth (2006b,c).

iv) Anchovy numbers-at-age in November 2005 were required and were taken from those predicted when testing OMP-04. No other changes to the anchovy input data were made.

Table A.1. Average directed sardine catch (in thousands of tons), $\overline{C}^S$ *, average sardine biomass at the end of the projection period as a proportion of carrying capacity and as a proportion of the biomass corresponding to the threshold used to define risk ("Risk"), and average minimum sardine biomass over the projection period as a proportion of carrying capacity and as a proportion of Risk, for the four alternative hypotheses for B* = 600. Statistics are given for 6 and 20 year projection periods both for all simulations ("All") and for the 10% of simulations resulting in the lowest biomass over the projection period ("Lower 10%").*

	H_{lowerB}				**H_0**			
	Final Year 2011		Final Year 2025		Final Year 2011		Final Year 2025	
	All	Lower 10%	All	Lower 10%	All	Lower 10%	All	Lower 10%
$\overline{C}^S$	167.19	111.20	180.32	90.80	183.87	134.43	187.66	111.55
$\overline{B^S_{final\ y}/K^S}$	0.63	0.26	0.69	0.38	0.64	0.31	0.70	0.45
$\overline{B^S_{final\ y}/Risk^S}$	1.58	0.59	1.77	0.82	1.60	0.68	1.82	0.95
$\overline{B^S_{\min}/K^S}$	0.39	0.19	0.34	0.08	0.46	0.22	0.38	0.10
$\overline{B^S_{\min}/Risk^S}$	0.98	0.43	0.86	0.18	1.16	0.51	0.95	0.21
$Risk^S$	0.57	0.57	0.68	0.68	0.42	0.42	0.61	0.61
	H_{lowB}				**H_{SR}**			
	Final Year 2011		Final Year 2025		Final Year 2011		Final Year 2025	
	All	Lower 10%	All	Lower 10%	All	Lower 10%	All	Lower 10%
$\overline{C}^S$	176.75	125.94	185.80	110.75	212.20	150.24	245.51	156.04
$\overline{B^S_{final\ y}/K^S}$	0.64	0.31	0.70	0.48	0.69	0.37	0.29	0.31
$\overline{B^S_{final\ y}/Risk^S}$	1.61	0.68	1.82	1.02	2.43	1.16	0.74	0.54
$\overline{B^S_{\min}/K^S}$	0.45	0.22	0.37	0.11	0.42	0.23	2.66	1.66
$\overline{B^S_{\min}/Risk^S}$	1.13	0.51	0.94	0.22	1.49	0.74	0.37	0.12
$Risk^S$	0.44	0.44	0.61	0.61	0.24	0.24	1.31	0.39

Table A.2. Average directed sardine catch (in thousands of tons), $\overline{C}^S$ *, for the four alternative hypotheses and four alternative choices for B*. Statistics are given for 6 and 20 year projection periods both for all simulations ("All") and for the 10% of simulations resulting in the lowest biomass over the projection period ("Lower 10%").*

	H_{lowerB}				**H_0**			
	Final Year 2011		Final Year 2025		Final Year 2011		Final Year 2025	
	All	Lower 10%	All	Lower 10%	All	Lower 10%	All	Lower 10%
B^* = 400	**170.30**	114.27	180.72	86.88	**185.50**	136.59	188.18	108.13
B^* = 600	**167.19**	111.20	180.32	90.80	**183.87**	134.43	187.66	111.55
B^* = 800	**164.58**	109.43	179.02	92.76	**181.92**	132.90	186.42	113.05
B^* = 1000	**162.86**	108.31	177.80	93.71	**180.17**	131.52	185.15	113.65
	H_{lowB}				**H_{SR}**			
	Final Year 2011		Final Year 2025		Final Year 2011		Final Year 2025	
	All	Lower 10%	All	Lower 10%	All	Lower 10%	All	Lower 10%
B^* = 400	**178.89**	128.51	186.36	107.20	**213.27**	152.85	245.48	153.16
B^* = 600	**176.75**	125.94	185.80	110.75	**212.20**	150.24	245.51	156.04
B^* = 800	**174.24**	123.66	184.44	112.60	**210.74**	147.81	245.08	157.16
B^* = 1000	**172.26**	122.13	183.15	113.65	**209.40**	146.19	244.50	157.56

Table A.3. Average directed sardine TAC (in thousands of tons) in 2007, 2008 and 2009 for the four alternative hypotheses and B = 600 and 800 thousand tons. Statistics are given both for all simulations ("All") and for the 10% of simulations resulting in the lowest biomass over the projection period ("Lower 10%").*

	$\mathbf{H_{lowerB}}$					
	All			Lower 10%		
Year	2007	2008	2009	2007	2008	2009
B^* = 600	166.300	156.446	156.728	138.445	112.360	90.393
B^* = 800	156.363	150.633	155.674	129.383	108.410	89.308
	$\mathbf{H_{lowB}}$					
	All			Lower 10%		
Year	2007	2008	2009	2007	2008	2009
B^* = 600	192.441	175.914	163.764	173.099	137.671	103.054
B^* = 800	186.453	169.816	160.775	164.197	131.684	100.765
	$\mathbf{H_0}$					
	All			Lower 10%		
Year	2007	2008	2009	2007	2008	2009
B^* = 600	218.612	191.851	168.371	199.949	157.970	107.854
B^* = 800	216.384	187.605	164.450	195.435	152.651	105.301
	$\mathbf{H_{SR}}$					
	All			Lower 10%		
Year	2007	2008	2009	2007	2008	2009
B^* = 600	218.612	206.054	202.753	199.949	166.273	124.943
B^* = 800	216.384	202.475	200.008	195.435	160.646	120.508