OMP-13: Further results for alternative anchovy harvest control rules

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de Moor and Butterworth (2013a,b) have shown some comparisons between alternative potential risk levels and harvest control rules for OMP-13. This document presents some further comparisons following requests arising at the OMP Task Team meeting on 22nd May 2013. The sardine base case operating model is that for a single stock used to develop Interim OMP-13 (de Moor and Butterworth 2012). The anchovy base case operating model assumes a Beverton Holt stock recruitment relationship with juvenile and adult natural mortality rates of 1.2year^{-1}.

Trade-off curves and summary statistics at the corresponding corner points are presented for three different anchovy Exceptional Circumstances thresholds of $B_{ec}^{A}=400$, $B_{ec}^{A}=600$ and $B_{ec}^{A}=800$. The form of the harvest control rules above and below the Exceptional Circumstances threshold remains the same, regardless of the threshold. Thus below the threshold the anchovy TAC is decreased quadratically, reaching zero at 100 000t, 150 000t and 200 000t, respectively (i.e. a quarter of the threshold). Comparisons are made between anchovy risk levels of $risk^{A}<0.15$, $risk^{A}<0.25$ and $risk^{A}<0.35$. Comparisons are also made between candidate MPs with an additional anchovy sub-season from October – December to ones with no additional sub-season. In the latter case the maximum anchovy normal season TAC of 450 000t is the only constraint on the increase in anchovy TAC following the May recruit survey results, while in the former case the post-recruit survey increase in the anchovy normal season TAC is constrained by a maximum of 150 000t.

Results and Discussion

Figure 1 shows trade-off curves for the three alternative anchovy risk levels and anchovy Exceptional Circumstances thresholds. Results are shown for MPs which assume no additional anchovy sub-season. Figure 1a shows results where the historic average back-projected recruitment used in the harvest control rule formula is based on a natural mortality rate of 0.9year^{-1}, while Figure 1b (and all other results presented) assumes a natural mortality rate of 1.2year^{-1} in this historic back-projected average. Results presented in earlier documents have been based on the lower historic average of 180 billion. However, if the base case operating models for anchovy will assume juvenile and adult natural mortality rates of 1.2year^{-1}, the higher value of 217 billion should be used. There is little difference in the average projected catches between Figures 1a and 1b, however, the key control parameter α_{ns} increases with an increase in this historic average. Table 1 lists the summary statistics corresponding to the corner points of the trade-off curves in Figure 1b.

As the anchovy Exceptional Circumstances threshold is increased, there is an increase in the average projected anchovy catch for the same anchovy risk level, with a smaller decrease in the average projected directed sardine catch.

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For example, when anchovy risk is constrained to a maximum of 0.25, the average projected anchovy catch increases from 256 to 275 to 282 thousand tonnes as the Exceptional Circumstances threshold increases from 400 to 600 and 800 thousand tonnes. The associated decrease in average projected directed sardine catch is from 159 to 154 to 153 thousand tonnes. The gain (increase) in average anchovy catch with increasing risk levels decreases in size for higher risk levels (Table 1, Figure 1b). As expected, the proportion of times anchovy Exceptional Circumstances are simulated to be declared increases both with increasing risk level and increasing Exceptional Circumstances threshold.

Figure 2 shows the trade-off curves for candidate MPs both with and without an additional anchovy sub-season, with the summary statistics for the corner points of these curves given in Table 2. This shows that for the same risk level, the removal of the additional season results in an increase in projected average anchovy catch and sardine bycatch with a resultant decrease in projected sardine bycatch. At the corner points of the trade-off curves, the average projected anchovy catch increases by 6-7000t if the additional season is removed. The average increase in sardine bycatch is 4 000t, with a projected average decrease of 5-7 000t of directed sardine catch.

Figures 3 to 6 present histograms of future simulated survey observations which form key inputs into the harvest control rule formulae. Histograms are presented for the corner points of the trade-off curves assuming $risk^A < 0.25$ with $B_{ec}^A = 400$ or $B_{ec}^A = 600$. Figures 3 and 5 show that the histogram of future simulated observations is highly skewed towards low values, but there is a long tail of values higher than historically observed. The medians of the skewed distributions are thus lower than the averages. The median projected observed November 1+ biomass is 1.2 million tonnes for $B_{ec}^A = 600$ and 1.5 million tonnes for $B_{ec}^A = 400$ with averages of 2.8 and 3.1 million tonnes, respectively. The median projected observed May recruitment, back-projected to November of the previous year to account for natural and fishing mortality, is 118 billion for $B_{ec}^A = 600$ and 138 billion for $B_{ec}^A = 400$, while the averages are 320 and 354 billion, respectively.

The weight of these histograms shifts slightly to the left (i.e., lower values) if the same harvest control rules are simulated using an alternative operating model. The alternative operating model used assumed a Hockey Stick stock recruitment relationship with estimated inflection point and natural mortality rates 1.2year^{-1} (Figures 3b and 5b).

Histograms of the ratio of these future simulated observations to the historic average are also shown (Figures 4 and 6) as this ratio used in the harvest control rule formulae (equations OMP.3 and OMP.10 of de Moor and Butterworth (2012)). Once again, the skewed distributions result in lower medians than averages. The median projected ratio for November 1+ biomass is 0.86 for $B_{ec}^A = 600$ and 1.11 for $B_{ec}^A = 400$, while the averages are 2.00 and 2.25, respectively. The median projected ratio for back-projected May recruitment is 1.14 for $B_{ec}^A = 600$ and 1.31 for

$B_{ec}^{A} = 400$, while the averages are 2.92 and 3.21, respectively. The shift of these histograms to the left under the alternative operating model is more pronounced.

References

de Moor, C.L. and Butterworth, D.S. 2012. Interim OMP-13. Department of Agriculture, Forestry and Fisheries Document FISHERIES/2012/DEC/SWG-PEL/64. 17pp.

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Table 1. Key summary statistics for the sardine and anchovy resources under a no-catch scenario and alternative constraints on the Harvest Control Rules for Candidate OMP-13:

- $risk^S$ - the probability that adult sardine biomass falls below the average adult sardine biomass over November 1991 to November 1994 (the "risk threshold", $Risk^S$) at least once during the projection period of 20 years;
- $risk^A$ - the probability that adult anchovy biomass falls below 10% of the average adult anchovy biomass between November 1984 and November 1999 at least once during the projection period of 20 years;
- average minimum biomass, $B_{\min}^{S/A}$, over the projection period as a proportion of carrying capacity ($K^{S/A}$) and as a proportion of the risk threshold;
- average biomass at the end of the projection period, $B_{2032}^{S/A}$, as a proportion of carrying capacity, as a proportion of the risk threshold, and as a proportion of biomass at the beginning of the projection period;
- average directed catch (in thousands of tons), $\overline{C}^S / \overline{C}^A$, and average anchovy catch during the additional season, $\overline{C}_{ad}^A$;
- average sardine bycatch comprising juvenile sardine bycatch with anchovy, round herring and large sardine (in thousands of tons), $\overline{C}_{by}^S$;
- average proportional annual change in directed catch, AAV^S / AAV^A;
- proportion of times the directed TAC decreases below the minimum TAC (i.e., Exceptional Circumstances are declared), $TAC_y^{A/S} < c_{mntac}^{A/S}$;
- average number of years for which Exceptional Circumstances, if declared, are declared consecutively, $EC_{con\sec}^{A/S}$;
- proportion of times the anchovy normal season fishery is closed due to the sardine TAB limit[1], $p(Close)$;
- average normal season anchovy catch lost in each of those years in which the fishery was closed, $\overline{C}_{lost}^A$; and
- average normal season anchovy TAC in years in which the fishery was closed $\overline{TAC}_{close}^A$.

Statistics are compared for the corner points from trade-off curves for candidate MPs which assume no additional season and three different anchovy Exceptional Circumstances thresholds ($B_{ec}^A = 400$, $B_{ec}^A = 600$ and $B_{ec}^A = 800$) against three different anchovy risk levels ($risk^A < 0.15$, $risk^A < 0.25$ and $risk^A < 0.35$).

[1] This is the proportion of times the revised normal season sardine TAB with anchovy is reached and excludes any times the initial normal season sardine TAB with anchovy may be reached.

Exceptional Circumstances Threshold		No Catch	400	400	600	600	600	800	800
Anchovy tuning risk level			0.25	0.35	0.15	0.25	0.35	0.15	0.25
Key Control Parameters	β		0.094	0.088	0.096	0.090	0.089	0.094	0.089
	α_{ns}		0.539	0.755	0.593	0.871	0.894	0.884	1.061
Risk statistics	$risk^S$	0.020	0.209	0.207	0.207	0.209	0.209	0.209	0.209
	$risk^A$	0.031	0.245	0.344	0.146	0.247	0.259	0.134	0.173
Anchovy depletion ratios	10%ile	1.00	0.14	0.10	0.22	0.15	0.14	0.22	0.19
	20%ile	1.00	0.23	0.14	0.28	0.18	0.18	0.24	0.22
	30%ile	1.00	0.33	0.19	0.34	0.22	0.21	0.27	0.23
	40%ile	1.00	0.38	0.25	0.39	0.26	0.25	0.31	0.26
	50%ile	1.00	0.43	0.31	0.41	0.29	0.28	0.33	0.29
Anchovy biomass statistics	$\overline{B^A_{\min}/K^A}$	0.22	0.11	0.09	0.11	0.09	0.09	0.10	0.09
	$\overline{B^A_{\min}/Risk^A}$	7.57	3.93	3.21	3.98	3.18	3.13	3.46	3.17
	$\overline{B^A_{2032}/K^A}$	1.17	0.65	0.55	0.66	0.55	0.55	0.59	0.56
	$\overline{B^A_{2032}/Risk^A}$	48.19	26.42	22.17	26.53	22.25	21.98	23.73	22.40
	$\overline{B^A_{2032}/B^A_{2011}}$	7.59	3.43	2.88	3.48	2.92	2.88	3.14	2.95
Anchovy catch statistics	$\overline{C}^A$ (‘13-‘32)	0	256	267	264	275	276	279	282
	$\overline{C}^A_{ad}$ (’13-’32)	0	0	0	0	0	0	0	0
	$\overline{C}^A$ (’13-‘15)	0	257	287	260	295	297	288	302
	$\overline{C}^A_{ad}$ (’13-’15)	0	0	0	0	0	0	0	0
	AAV^A (’13-‘32)		0.23	0.21	0.23	0.19	0.19	0.19	0.18
	AAV^A (‘13-‘15)		0.15	0.13	0.14	0.13	0.13	0.13	0.13
Sardine biomass statistics	$\overline{B^S_{\min}/K^S}$	0.54	0.41	0.41	0.41	0.41	0.41	0.41	0.41
	$\overline{B^S_{\min}/Risk^S}$	2.03	1.56	1.56	1.56	1.56	1.56	1.55	1.56
	$\overline{B^S_{2032}/K^S}$	0.99	0.75	0.75	0.74	0.74	0.74	0.74	0.74
	$\overline{B^S_{2032}/Risk^S}$	4.04	3.00	3.01	2.99	2.99	2.99	2.97	2.99
	$\overline{B^S_{2032}/B^S_{2011}}$	1.99	1.45	1.45	1.44	1.44	1.44	1.43	1.44
Sardine catch statistics	$\overline{C}^S$ (‘13-‘32)	0	159	152	161	154	153	159	153
	$\overline{C}^S_{by}$	0	34	38	33	39	39	37	39
	$\overline{C}^S$ (‘13-‘15)	0	129	124	131	125	125	129	125
	AAV^S (‘13-‘32)		0.21	0.20	0.21	0.19	0.19	0.20	0.19
	AAV^S (‘13-‘15)		0.04	0.04	0.04	0.04	0.04	0.04	0.04
Anchovy Exceptional Circumstances	$p\left(TAC^A_y < c^A_{mntac}\right)$		0.17	0.23	0.22	0.30	0.31	0.35	0.39
	$EC^A_{con\sec}$		3.37	3.55	3.02	3.43	3.46	3.39	3.57
Anchovy Fishery Closure	$p(Close)$		0.23	0.25	0.23	0.26	0.26	0.26	0.27
	$\overline{C}^A_{lost}$		31	32	32	33	33	33	33
	$\overline{TAC}^A_{close}$		139	138	142	139	139	138	140
Sardine Exceptional Circumstances	$p\left(TAC^S_y < c^S_{mntac}\right)$		0.05	0.05	0.05	0.05	0.05	0.05	0.05
	$EC^S_{con\sec}$		1.34	1.33	1.32	1.35	1.35	1.33	1.33

Table 2. Key summary statistics as for Table 1, but for candidate MPs which assume an additional season from October – December and for candidate MPs which assume no additional season for two different anchovy Exceptional Circumstances thresholds with different anchovy risk levels ($B_{ec}^{A} = 400$ with $risk^{A} < 0.35$, and $B_{ec}^{A} = 600$ with $risk^{A} < 0.20$).

Exceptional Circumstances Threshold		No Catch	400		600	
Anchovy tuning risk level			0.35		0.20	
Additional season			Oct-Dec	No	Oct-Dec	No
Key Control Parameters	β		0.094	0.088	0.098	0.094
	α_{ns}		0.588	0.755	0.581	0.726
Risk statistics	$risk^S$	0.020	0.207	0.207	0.209	0.209
	$risk^A$	0.031	0.348	0.344	0.194	0.196
Anchovy depletion ratios	10%ile	1.00	0.11	0.10	0.19	0.18
	20%ile	1.00	0.14	0.14	0.22	0.22
	30%ile	1.00	0.17	0.19	0.25	0.28
	40%ile	1.00	0.23	0.25	0.28	0.32
	50%ile	1.00	0.27	0.31	0.31	0.35
Anchovy biomass statistics	$\overline{B^A_{\min}/K^A}$	0.22	0.08	0.09	0.09	0.10
	$\overline{B^A_{\min}/Risk^A}$	7.57	2.81	3.21	3.15	3.55
	$\overline{B^A_{2032}/K^A}$	1.17	0.52	0.55	0.57	0.60
	$\overline{B^A_{2032}/Risk^A}$	48.19	20.55	22.17	22.70	24.24
	$\overline{B^A_{2032}/B^A_{2011}}$	7.59	3.18	2.88	3.56	3.18
Anchovy catch statistics	$\overline{C}^A$ ('13-'32)	0	260	267	266	272
	$\overline{C}^A_{ad}$ ('13-'32)	0	49	0	51	0
	$\overline{C}^A$ ('13-'15)	0	276	287	267	279
	$\overline{C}^A_{ad}$ ('13-'15)	0	48	0	49	0
	AAV^A ('13-'32)		0.18	0.21	0.18	0.21
	AAV^A ('13-'15)		0.05	0.13	0.05	0.13
Sardine biomass statistics	$\overline{B^S_{\min}/K^S}$	0.54	0.41	0.41	0.41	0.41
	$\overline{B^S_{\min}/Risk^S}$	2.03	1.56	1.56	1.56	1.56
	$\overline{B^S_{2032}/K^S}$	0.99	0.74	0.75	0.74	0.74
	$\overline{B^S_{2032}/Risk^S}$	4.04	3.00	3.01	2.98	2.98
	$\overline{B^S_{2032}/B^S_{2011}}$	1.99	1.45	1.45	1.44	1.44
Sardine catch statistics	$\overline{C}^S$ ('13-'32)	0	159	152	164	159
	$\overline{C}^S_{by}$	0	34	38	32	36
	$\overline{C}^S$ ('13-'15)	0	129	124	133	129
	AAV^S ('13-'32)		0.20	0.20	0.21	0.20
	AAV^S ('13-'15)		0.04	0.04	0.04	0.04
Anchovy Exceptional Circumstances	$p\left(TAC^A_y < c^A_{mntac}\right)$		0.25	0.23	0.30	0.26
	EC^A_{consec}		3.45	3.55	3.16	3.19
Anchovy Fishery Closure	$p(Close)$		0.28	0.25	0.27	0.24
	$\overline{C}^A_{lost}$		26	32	26	33
	$\overline{TAC}^A_{close}$		114	138	114	141
Sardine Exceptional Circumstances	$p\left(TAC^S_y < c^S_{mntac}\right)$		0.05	0.05	0.05	0.05
	EC^S_{consec}		1.35	1.33	1.33	1.33

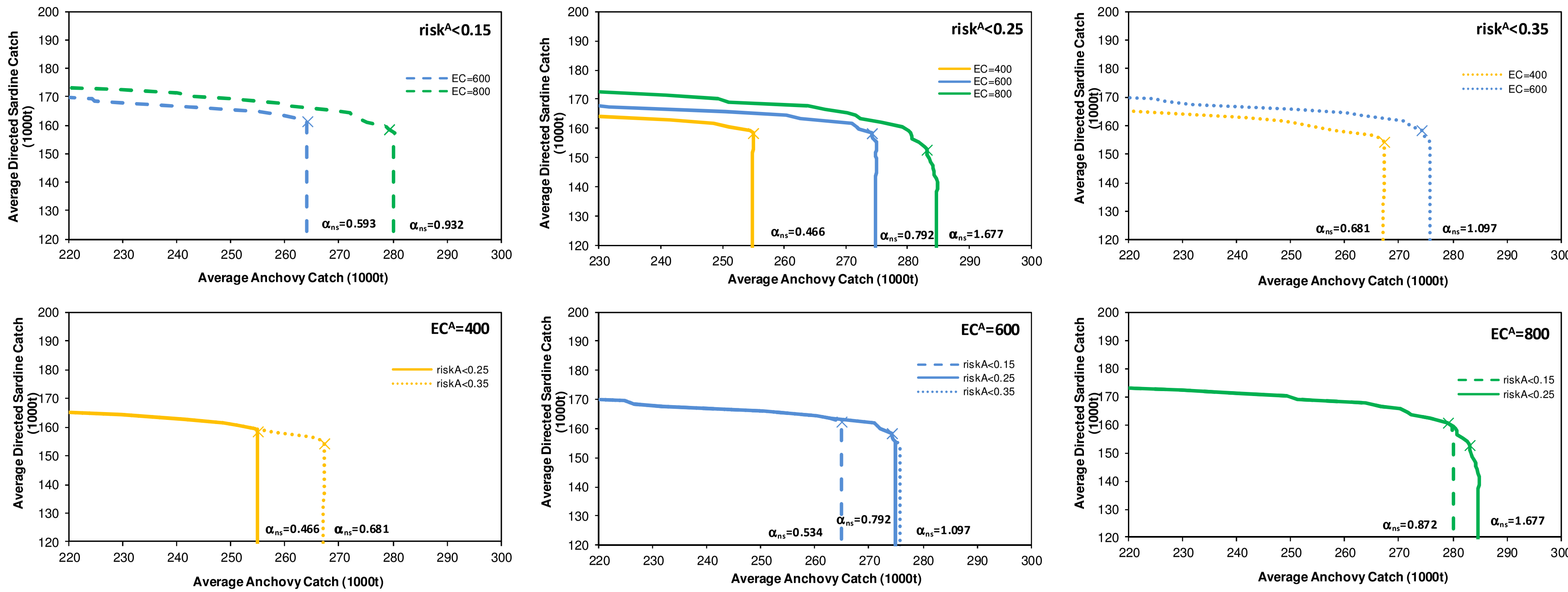

Figure 1a. Trade-off curves comparing three alternative anchovy Exceptional Circumstances thresholds; $B_{ec}^{A}=400$, $B_{ec}^{A}=600$ and $B_{ec}^{A}=800$ (upper panel) and three alternative anchovy risk levels; $risk^{A}<0.15$, $risk^{A}<0.25$ and $risk^{A}<0.35$ (lower row). All curves are based on a candidate MP which assumes no additional season and the back-projected average historic recruitment of 180 billion is calculated assuming $M_{j}^{A}=M_{ad}^{A}=0.9\,\text{year}^{-1}$. The crosses indicate the "corner points" chosen for which performance statistics are presented in Table 1. The α_{ns} values inserted next to the curves denote the maximum α_{ns} achieved when $\beta=0$.

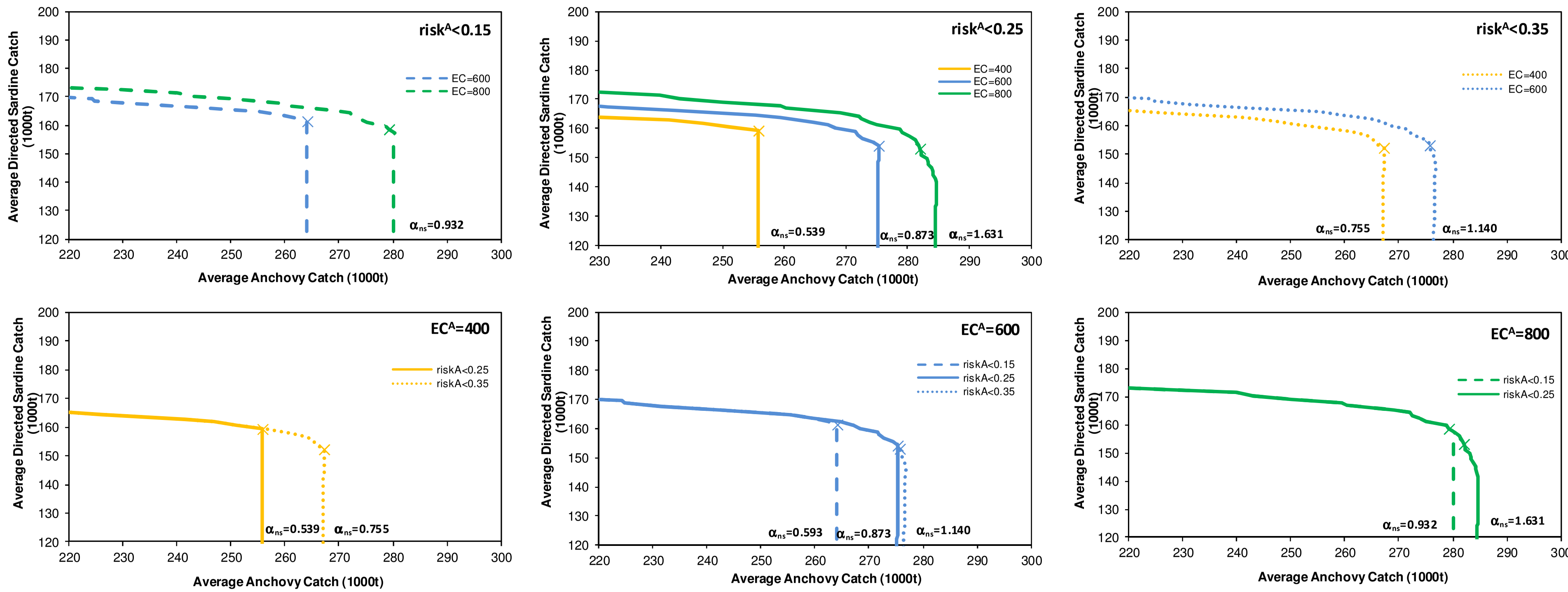

Figure 1b. Trade-off curves comparing three alternative anchovy Exceptional Circumstances thresholds; $B_{ec}^{A} = 400$, $B_{ec}^{A} = 600$ and $B_{ec}^{A} = 800$ (upper panel) and three alternative anchovy risk levels; $risk^{A} < 0.15$, $risk^{A} < 0.25$ and $risk^{A} < 0.35$ (lower row). All curves are based on a candidate MP which assumes no additional season and the back-projected average historic recruitment of 217 billion is calculated assuming $M_{j}^{A} = M_{ad}^{A} = 1.2\ \text{year}^{-1}$. The crosses indicate the "corner points" chosen for which performance statistics are presented in Table 1. The α_{ns} values inserted next to the curves denote the maximum α_{ns} achieved when $\beta = 0$.

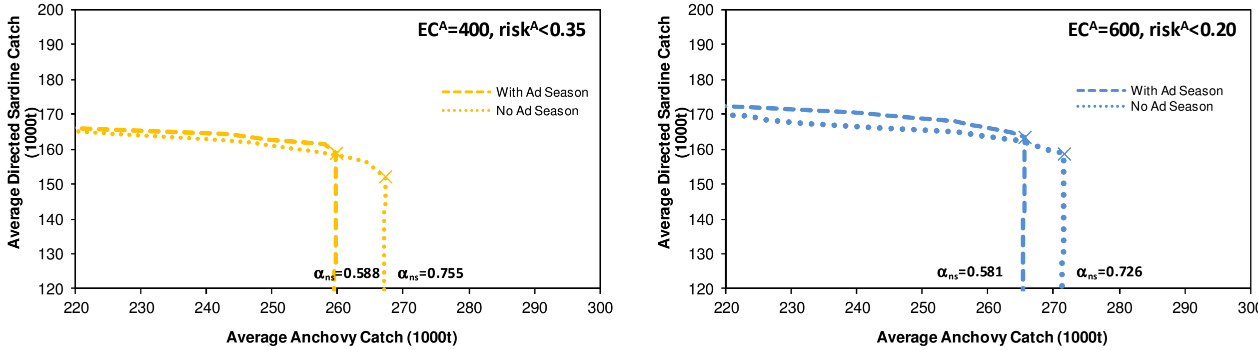

Figure 2. Trade-off curves comparing a candidate MP with an additional season from October – December to one with no additional season. Curves are shown for $B_{ec}^{A} = 400$ with $risk^{A} < 0.35$ and for $B_{ec}^{A} = 600$ with $risk^{A} < 0.20$. The crosses indicate the "corner points" chosen for which performance statistics are presented in Table 2. The α_{ns} values inserted next to the curves denote the maximum α_{ns} achieved when $\beta = 0$.

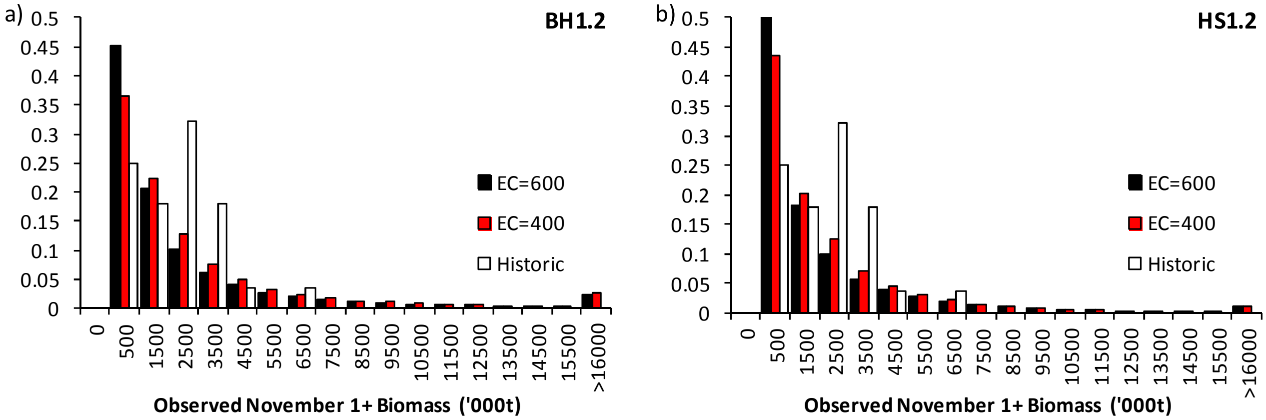

Figure 3. Histograms of the simulated future observed November 1+ biomass together with a histogram of the 1984-2011 observations for a) the corner points of trade-off curves assuming no additional season, $risk^A < 0.25$ and either $B_{ec}^A = 400$ ($\beta = 0.094$, $\alpha_{ns} = 0.539$) or $B_{ec}^A = 600$ ($\beta = 0.090$, $\alpha_{ns} = 0.871$), and b) the same harvest control rule and parameters, but assuming an alternative underlying operating model.

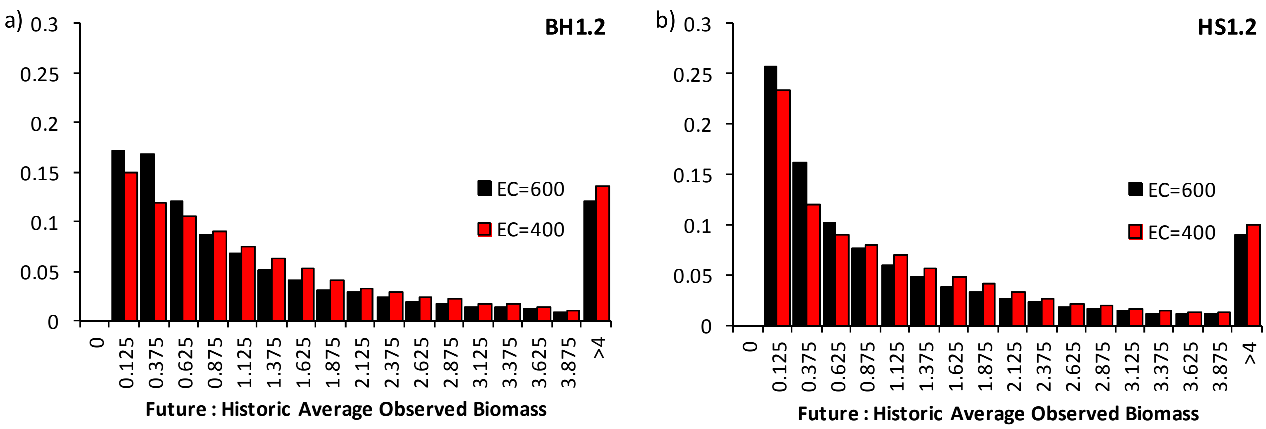

Figure 4. Histograms of the ratio of simulated future observed November 1+ biomass to the historic average (1380 000t) for a) the corner points of trade-off curves assuming no additional season, $risk^A < 0.25$ and either $B_{ec}^A = 400$ ($\beta = 0.094$, $\alpha_{ns} = 0.539$) or $B_{ec}^A = 600$ ($\beta = 0.090$, $\alpha_{ns} = 0.871$), and b) the same harvest control rule and parameters, but assuming an alternative underlying operating model.

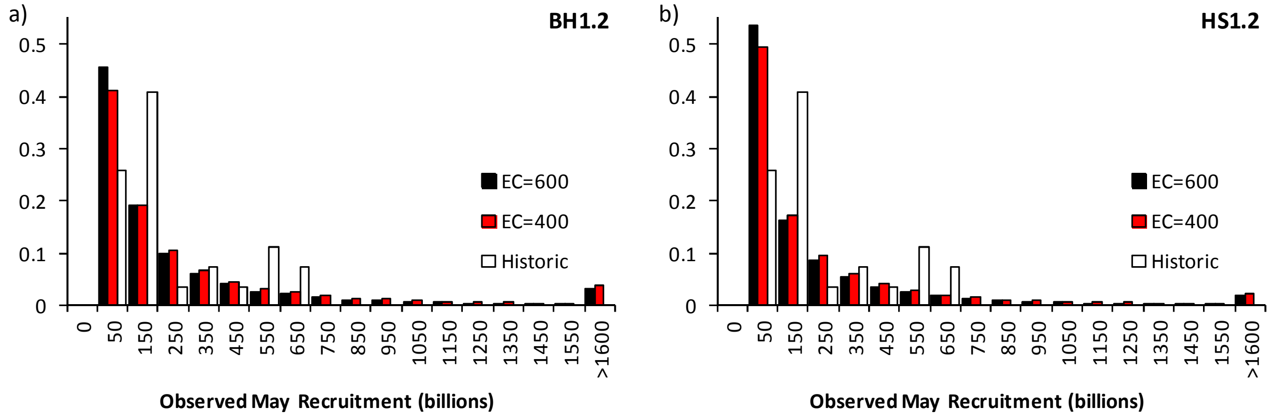

Figure 5. Histograms of the simulated future back-projected observed May recruitment together with a histogram of the 1985-2011 observations for a) the corner points of trade-off curves assuming no additional season, $risk^{A} < 0.25$ and either $B_{ec}^{A} = 400$ ($\beta = 0.094$, $\alpha_{ns} = 0.539$) or $B_{ec}^{A} = 600$ ($\beta = 0.090$, $\alpha_{ns} = 0.871$), and b) the same harvest control rule and parameters, but assuming an alternative underlying operating model.

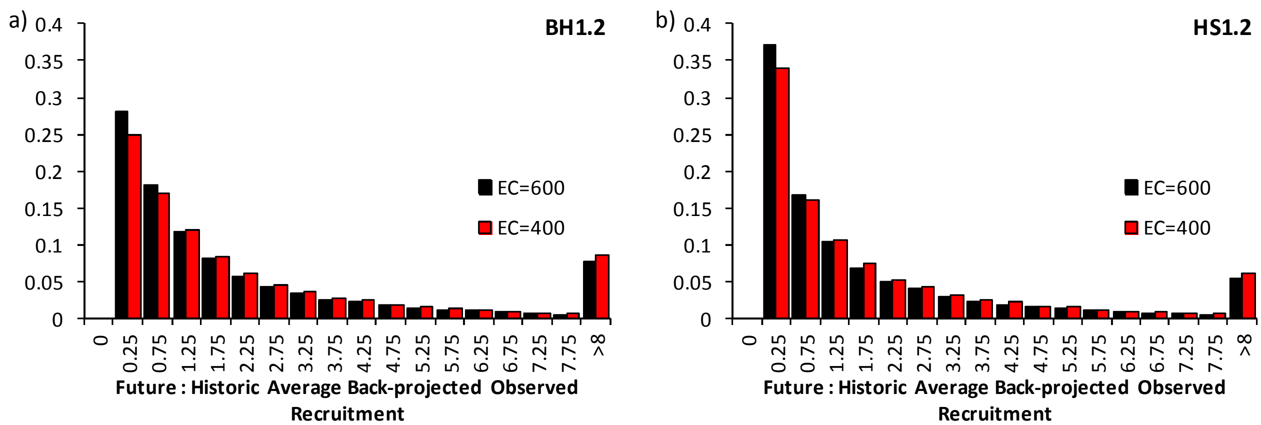

Figure 6. Histograms of the ratio of simulated future observed November 1+ biomass to the historic average (217 billion) for a) the corner points of trade-off curves assuming no additional season, $risk^{A} < 0.25$ and either $B_{ec}^{A} = 400$ ($\beta = 0.094$, $\alpha_{ns} = 0.539$) or $B_{ec}^{A} = 600$ ($\beta = 0.090$, $\alpha_{ns} = 0.871$), and b) the same harvest control rule and parameters, but assuming an alternative underlying operating model.