Some Initial Results in the Development of OMP-18rev

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The methodology and Operating Models (OMs, including implementation error and observation error) to be used to simulation test OMP-18rev have been fully specified in de Moor (2020a). In this document, some diagnostics are firstly used as a check to ensure that future projections of the sardine and anchovy resources using these OMs are in line with expectations, given what has been observed historically. Some initial results of candidate anchovy Harvest Control Rules (HCRs) under multiple OMs are considered.

No Future Catch

Figures 1 and 2 show that the November biomass is projected to be within the same range as that observed historically, noting that sardine projections exclude the possibility of a recruitment pulse (i.e. west coast stock recruitment is based on years excluding Novembers 2000 – 2002).

Figures 3a and 4a show the full range of historically estimated (grey) and future simulated (red) (effective) spawner biomass and recruitment pairs. Of particular importance is that the range of future recruitments (the vertical axis) is similar to that historically estimated. This 'matching' range results from (i) restricting future standardised residuals to be within the same range as that historically estimated and then additionally (ii) restricting future recruitments to the 99%ile of that historically estimated in the peak recruitment year for anchovy and the 99%ile of that historically estimated in all years excluding the pulse recruitment years for west component sardine (de Moor 2020a). As a reminder, a Beverton Holt stock recruitment relationship is assumed for anchovy (historically and in the future), a Hockey Stick stock recruitment relationship is assumed for west component sardine in 'non-pulse' years (fitted after conditioning historical estimates, and assumed in the future) and a 'two-step' stock recruitment relationship is assumed for south component sardine (estimated after conditioning historical estimates, and assumed in the future).

Figures 5 and 6 then show the time series of November recruitment, similarly showing future recruitment to be within the same range as that estimated historically (excluding pulse recruitment years of 2000-2002 for west component sardine). Further plots are given in Appendix 1.

The future 'observations' generated for the recruit surveys (assumed to take place mid-May each year) are compared against those historically observed in Figures 7 and 8. The June 2020 survey estimate is shown together with that predicted from the OM which is conditioned on data up to November 2019. Importantly, the estimate (with variance) observed is within the range of that predicted. de Moor (2020a) differs from, for example, de Moor (2018a) and de Moor and Butterworth (2013) in that the recruitment in the initial year (November 2019 in this case) is taken from the

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stock recruitment relationship only and not inverse variance weighted with both the stock recruitment relationship and the subsequent survey estimate (together with catch observations prior to the survey). This decision was based on the relatively high weighting given to the recent survey estimate using the previous method. The declaration of Exceptional Circumstances from OMP-18 resulted from the influence of a recent 'high' survey estimate that wasn't realised in practice and thus future observations were outside the range of that simulated in those years. The implications of this assumption are discussed further in the 'June 2020 survey recruitment' section below.

Method(s) to arrive at an anchovy HCR for OMP-18rev

Risk measures for the sardine and anchovy populations have been defined as (de Moor 2018b):

$Risk_S$: the probability of the sardine west component effective spawner biomass[1] being below that of the 2007[2] level over the projection period.

$Risk_A$: the probability of the anchovy spawner biomass being below that of the 1996[3] level over the projection period.

The acceptable level of risk (i.e. acceptable probability) changes from one management procedure to the next, given changes in the perceived level of productivity of a resource resulting from the inclusion of revised and new data when conditioning the underlying OMs.

All catch alternatives (except OMP-14) presented in this document use the OMP-18 sardine HCR, with $\beta = 0.124$. In this document only risk to the anchovy resource together with other anchovy-related performance statistics are considered under alternative anchovy HCRs. Alternative sardine HCRs will be considered in a separate document.

Key performance statistics for the baseline OM, A_{BH}, are shown in Table 1. Under a no future catch scenario, the risk to the anchovy resource is simulated to be higher given 4 more years data than that simulated using the OM based on data up to 2015. The increase in risk under a no catch scenario is 1.2% (from 0.018 to 0.030). The risk under OMP-18, however, increases by 12.9% from the old OM to A_{BH}.

As the 'leftward shift' method could not be followed for anchovy, the OMP-18 key control parameter of the anchovy HCR, α, was selected to match the maximum risk ($Risk_A = 0.089$) resulting from applying OMP-14 to the OM used to develop OMP-18. Applying OMP-14 to A_{BH} results in $Risk_A = 0.181$ (Table 1) and repeating this previous method gives a CMP ("CMP3"), with $\alpha = 0.936$ tuned to have $Risk_A = 0.181$. The annual anchovy catch under CMP3 is simulated to range from 11 to 350 000t, with a median of 350 000t and an average of 274 000t. Although the risk to the resource is simulated to be less under CMP3 than under OMP-18, the risk under this catch alternative is still 9.2% more than that accepted at the time that OMP-18 was implemented (compared to 1.2% more under a no catch scenario). The annual risk[4] in the short-term under CMP3 is 6 to 12% higher than a no catch scenario.

[1] The sardine found off the west and south coasts of South Africa do not form a single homogeneous stock (de Moor *et al*. 2017). The baseline Operating Model used to simulation test Management Procedures for South African sardine assumes two sardine components, distributed west and south-east of Cape Agulhas, with some mixing between them. The 'effective spawner biomass' for the west component is defined as the west component spawner biomass together with an additional proportion (8% used when tuning OMP-18) of the south component spawner biomass.

[2] 2007 is the lowest historical year since 2000 for the baseline sardine Operating Models.

[3] 1996 is the lowest historical year since 2000 for the baseline anchovy Operating Model.

[4] The probability of the anchovy spawner biomass is below the 1996 level in a particular year.

There is currently little concern to the anchovy resource when biomass and recruitment levels are high – in fact the anchovy resource is probably substantially under-utilised from an industry perspective during very good recruitment years due to the cap on the maximum anchovy TAC imposed primarily due to industry constraints in catching higher quotas. However, increased risk to the anchovy resource occurs at low biomass and recruitment levels. Thus, an alternative CMP ("CMP4") adjusts the HCR at the lower end, by increasing B^A_{crit} from 600 to 900 thousand tons without adjusting the control parameter, α. This results in a reduction to both the short-term and long-term risk statistics with little 'loss' from a catch perspective: $Risk_A$ reduces from 0.181 to 0.140, average catch reduces from 274 000 to 270 000t and median catch remains unchanged at 350 000t (Table 1). Figure 9 shows there is little change in the distribution of realised anchovy catch[5] for high catches, but some shift in the distribution for catches less than 250 000t. Two CMPs with intermediate values of 800 and 700 thousand tons for B^A_{crit} (CMP5 and CMP6) have also been considered, with lower 'gains' in the risk statistic for lower B^A_{crit} values. Finally, "CMP7" provides a comparison if $\alpha = 1.16$ (from OMP-18) and $B^A_{crit} = 900$ thousand tons. CMP4, CMP5 and CMP6 have been favoured by SWG-PEL TTG members.

The simulated distribution of initial anchovy TAC is more spread out compared to the distribution of realised catch, primarily due to the maximum (final) TAC of 350 000t being taken in the majority of simulations (Figure 10).

June 2020 survey recruitment

A method to 'quickly' check whether the generation of 2019 recruitment without explicitly using the June 2020 survey estimate within the OM influences the tuning of the CMP was undertaken. This 'upper recruitment extreme' simply considered the 500 simulations (out of 1000) corresponding to the highest simulated mid-May 2020 survey 'observations' only, thereby ensuring that performance statistics were calculated only from simulations which corresponded to those which produced May 2020 estimates within the confidence intervals of the June 2020 survey observation (Figure 11). This is more 'extreme' than the inverse variance weighting previously used (de Moor 2018a), but was quicker to implement for sensitivity testing purposes only. "CMP8", tuned in the same method as CMP3, but using this 'upper recruitment extreme' OM results in a similar α to CMP3 (Table 2), showing that the selection of α is relatively insensitive to the method used to generate 2019 recruitment. The current OM is preferred as it allows for testing of CMPs over a greater range of uncertainty w.r.t incoming recruitment, and therefore, hopefully, a lower chance of Exceptional Circumstances being required in the short term if the recruitment from the June 2020 survey is once again not fully 'realised' in the population.

Table 2 and Figure 12 also show that if CMP3 or CMP4 were implemented and the underlying population dynamics were indeed similar to this 'upper recruitment regime', then the average catch will increase from that simulated using A_{BH}, there would be a lower chance of the critical biomass metarule being used and the biomass at the end of the projection period would be higher.

[5] This differs from the final TAC in situations where a maximum of 95% of anchovy biomass is taken and/or where the anchovy fishery is simulated to be closed due to the sardine bycatch limit being reached.

Maximum anchovy catch

The CMPs in Table 1 (and OMP-18) all have a maximum anchovy TAC of 350 000t. Since 2000, industry has only once landed more than 300 000t of anchovy, despite often having TACs of 350 to 450 000t. Table 3 shows the performance statistics if the maximum anchovy TAC is decreased to 275 000t. The average and median anchovy catches decrease as expected, with medians again matching the maximum TAC. There is a small decrease in short-term risk and a greater decrease in long term risk to the resource.

Robustness Testing

One of the key reasons for undertaking Management Strategy Evaluation is to be able to simulation test CMPs while taking into account a range of plausible uncertainties. Tables 4 and 5 shows the key performance statistics for CMP5 and CMP6 under plausible alternative OMs (de Moor 2020b). The performance statistics under a range of OMs to another CMP is shown in Appendix B. For ease of reference, these are defined again here:

A_{2BH} - Two Beverton Holt stock-recruitment curves, with uniform priors on steepness and carrying capacity, one estimated using data from 1984 to 1999 and the other from 2000 to 2019.

A_{2BHrtn} - Two Beverton Holt stock-recruitment curves, with uniform priors on steepness and carrying capacity, one estimated using data from 1984 to 1999 and 2013 to 2019, and the other from 2000 to 2012.

A_{R} - Ricker stock-recruitment curve, with uniform priors on steepness and carrying capacity.

A_{HS} - Hockey stick stock-recruitment curve, with uniform priors on the log of the maximum recruitment and on the ratio of the spawning biomass at the inflection point to carrying capacity.

A_{M1} - $\bar{M}_j^A = \bar{M}_{ad}^A = 0.9$ (for comparison with the baseline assessment of 2007)

A_{M2} - $\bar{M}_j^A = 1.5$ and $\bar{M}_{ad}^A = 1.2$ (alternative $\bar{M}_j^A$, similar to A_{BH} in terms of value of the negative log joint posterior mode)

A_{Mad} - Annually varying adult natural mortality, i.e. random effects model with $\sigma_{ad} = 0.2$ and $\rho \sim U(0,1)$.

A_{Mj} - Annually varying juvenile natural mortality, i.e. random effects model with σ_j =0.2 and $\rho \sim U(0,1)$.

A_{M2000+} - Natural mortality assumed to have increased in 2000; i.e. $\bar{M}_j^A = \bar{M}_{ad}^A = 1.2$year^{-1} prior to 2000 and $\bar{M}_j^A = \bar{M}_{ad}^A = 1.5$ year^{-1} from 2000 onwards. The Beverton-Holt stock recruitment relationship was estimated to correspond to the years 2000 onwards, with no stock-recruitment relationship assumed prior to 2000.

A_{4} - No plus group, all remaining fish assumed to die as they reach age 5.

A_{DD} - Density dependent natural mortality: $\bar{M}_{j,y}^A = \bar{M}_{ad,y}^A = \bar{M} + e^{-\chi B_{y-1}^A}$.

A_{sur} - Survey selectivity below 7.5cm was estimated to be a constant, and uniform (1) selectivity was assumed for lengths ≥7.5cm.

A_{com2} - Commercial selectivity was modelled using a double-logistic curve.

A_{kegg} - Egg survey bias estimated with uninformative prior, i.e. $ln(k_g^A) \sim U(-100,0.7)$.

A_{lamR} - Additional variance (over and above the survey sampling CV) associated with the recruit survey fixed $(\lambda_r^A)^2$=0.

A_{lamN2} - Additional variance (over and above the survey sampling CV) associated with the November survey fixed $(\lambda_N^A)^2 = 0.02$.

As the true population dynamics are uncertain, any selected CMP should be robust to plausible uncertainties in these underlying population dynamics.

As expected, the risk to the resource decreases, and average catch increases, under the more optimistic recruitment scenarios of A_{2BH} and A_{HS}, and the less uncertain recruitment survey scenario of A_{lamR}.

The performance statistics suggest CMP5 and CMP6 are robust to the uncertainties in A_{BH} represented by A_{Mj}, A_4, A_{kegg} and A_{lamN2}. The catches under CMP5 and CMP6 are also robust to the uncertainty in the commercial selectivity (A_{com2}), with some increase in risk to the resource under this scenario.

The risk to the resource will be higher, and average anchovy catch lower if the Beverton Holt stock recruitment relationship is a more pessimistic than A_{BH} (i.e. A_{2BHrtn}), if the stock-recruitment is closer to a Ricker relationship or if there is density dependence in natural mortality together with a time-invariant stock recruitment relationship. Increases in time invariant natural mortality or annually varying adult natural mortality also result in a higher resource risk and lower average anchovy catches.

In selecting a CMP one needs to consider (among other things) if the risk to the resource would be too higher should 'reality' differ from that assumed for the baseline OM. The greatest risk to the resource would result under A_R, A_{M2}, A_{M1} and A_{Mad}, with a 26% and 24% chance of the anchovy spawner biomass being below the 1996 level under A_R for CMP6 and CMP5, respectively.

Next Steps

Candidate MPs with sardine HCRs which differ from that used in OMP-18 will now be considered in a similar manner to how CMPs with different anchovy HCRs have been developed. There is feedback between sardine and anchovy in this joint sardine-anchovy OMP. The anchovy HCR has been developed first as anchovy catch typically has a greater impact on the sardine resource than sardine bycatch limits have on the anchovy resource. However, once a preferred sardine HCR has been selected, some small joint adjustments to the anchovy and sardine control parameters may be required to maintain the same methodology/risk as used in this document.

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Table 1. Key summary performance statistics assuming the baseline OM of A_{BH} for a no catch scenario, OMP-18, OMP-14, a CMP tuned to the same risk level as OMP-14: "CMP3", CMP3 with $B^A_{crit} = 900$, termed "CMP4", CMP3 with $B^A_{crit} = 800$, termed "CMP5", CMP3 with $B^A_{crit} = 700$, termed "CMP6", and a CMP with the same α as OMP-18 and with $B^A_{crit} = 900$, termed "CMP7". The first columns additionally show the performance statistics under a no catch scenario and OMP-18 using the OM available in 2018. Where appropriate, medians and 90% probability intervals are provided, and for some statistics the means are provided additionally and shown in **bold**. All biomasses are given in thousands of tons.

	OM using data up to 2015		A_{BH}							
	No Catch	OMP-18	No Catch	OMP-18	OMP-14	CMP3	CMP4	CMP5	CMP6	CMP7
β	-	0.124	-	0.124	0.0869	0.124	0.124	0.124	0.124	0.124
α	-	1.16	-	1.16	0.889	0.936	0.936	0.936	0.936	1.16
$Risk_S$	0.070	0.153	0.061	0.227	0.210	0.224	0.222	0.223	0.224	0.225
$Risk_A$	0.018	0.089	0.030	0.218	0.181	0.181	0.140	0.153	0.167	0.160
$p(B^{sp,A}_{2020} < B^{sp,A}_{1996})$			0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
$p(B^{sp,A}_{2021} < B^{sp,A}_{1996})$			0.08	0.15 (+7)	0.14 (+6)	0.14 (+6)	0.12 (+4)	0.13 (+5)	0.14 (+6)	0.13 (+5)
$p(B^{sp,A}_{2022} < B^{sp,A}_{1996})$			0.05	0.17 (+12)	0.15 (+10)	0.15 (+10)	0.13 (+8)	0.14 (+9)	0.15 (+10)	0.15 (+10)
$p(B^{sp,A}_{2023} < B^{sp,A}_{1996})$			0.04	0.19 (+15)	0.15 (+11)	0.16 (+12)	0.12 (+8)	0.13 (+9)	0.14 (+10)	0.15 (+11)
$p(B^{sp,A}_{2024} < B^{sp,A}_{1996})$			0.04	0.20 (+16)	0.17 (+13)	0.16 (+12)	0.13 (+9)	0.14 (+10)	0.15 (+11)	0.15 (+11)
$B^{sp,A}_{2036}$ or $B^{sp,A}_{2040}$	**3384** 2341	**2669** 1613	**2920** 2344 [654,7178]	**1808** 1176 [132,5721]	**1784** 1156 [178,5575]	**1890** 1254 [182,5896]	**1984** 1330 [265,6139]	**1954** 1317 [228,5923]	**1923** 1287 [207,5910]	**1935** 1264 [225,5918]
$B^{sp,A}_{2036}/B^{sp,A}_{2019}$ or $B^{sp,A}_{2040}/B^{sp,A}_{2019}$	1.6	1.1	1.9 [0.4,8.7]	0.9 [0.1,6.4]	0.9 [0.1,6.2]	1.0 [0.1,6.4]	1.1 [0.1,6.7]	1.0 [0.1,6.7]	1.0 [0.1,6.5]	1.0 [0.1,6.7]
$B^{sp,A}_{2036}/B^{sp,A}_{1996}$ or $B^{sp,A}_{2040}/B^{sp,A}_{1996}$	4.9	3.4	5.0 [1.4,15.7]	2.4 [0.3,12.5]	2.4 [0.3,12.1]	2.6 [0.4,12.6]	2.8 [0.5,12.7]	2.7 [0.5,12.6]	2.7 [0.4,12.7]	2.6 [0.5,12.6]
$B^{sp,A}_{2036}/K^A$ or $B^{sp,A}_{2040}/K^A$	1.2	0.9	0.7 [0.2,2.0]	0.4 [0.0,1.6]	0.4 [0.0,1.6]	0.4 [0.0,1.6]	0.4 [0.1,1.7]	0.4 [0.1,1.7]	0.4 [0.1,1.7]	0.4 [0.1,1.7]
$B^{sp,A}_{min}$	920	543	816 [263,1742]	296 [64,1093]	340 [80,1027]	350 [77,1094]	409 [115,1094]	390 [103,1094]	370 [90,1094]	368 [104,1093]
$B^{sp,A}_{min}/B^{sp,A}_{1996}$	2.0	1.2	1.65 [0.55,4.06]	0.60 [0.13,2.44]	0.69 [0.17,2.26]	0.71 [0.16,2.52]	0.84 [0.25,2.52]	0.80 [0.22,2.52]	0.76 [0.19,2.52]	0.76 [0.22,2.44]
$B^{sp,A}_{min}/K^A$	0.5	0.3	0.25 [0.07,0.50]	0.09 [0.02,0.31]	0.10 [0.02,0.31]	0.11 [0.02,0.33]	0.13 [0.03,0.34]	0.12 [0.02,0.33]	0.11 [0.02,0.33]	0.12 [0.03,0.32]
C^A	**11** 0 [0,0]	**311** 350	**0** 0 [0,0]	**281** 350 [5,350]	**310** 341 [9,450]	**274** 350 [11,350]	**270** 350 [7,350]	**272** 350 [8.350]	**273** 350 [10,350]	**277** 350 [5.350]
Med C^A [6]	0 [0,0]	350	0 [0,0]	350 [51,350]	350 [70,450]	349 [74,350]	350 [61,350]	350 [66,350]	349 [69,350]	350 [57,350]
C^A_{now} [7]	0 [0,0]	350	0 [0,0]	350 [23,350]	350 [27,450]	350 [34,350]	350 [15,350]	350 [20,350]	350 [25,350]	350 [13,350]
MAV^A [8]	-	0.00	-	0.04 [0.00,0.87]	0.25 [0.00,0.81]	0.12 [0.00,0.76]	0.13 [0.00,0.80]	0.13 [0.00,0.79]	0.12 [0.00,0.76]	0.03 [0.00,0.84]
$p(B^{Aobs}_y < B^A_{crit}, B_y < B^A_{crit}/k^A_N)$	-	0.07	-	0.22	0.19	0.19	0.26	0.23	0.21	0.29
$p(B^{Aobs}_y < B^A_{crit}, B_y \geq B^A_{crit}/k^A_N)$	-	0.01	-	0.03	0.03	0.03	0.04	0.04	0.03	0.04
$p(B^{Aobs}_y \geq B^A_{crit}, B_y < B^A_{crit}/k^A_N)$	-	0.01	-	0.03	0.03	0.02	0.04	0.03	0.03	0.04
$p(B^{Aobs}_y \geq B^A_{crit}, B_y \geq B^A_{crit}/k^A_N)$	-	0.91	-	0.73	0.75	0.76	0.66	0.69	0.73	0.64
Avg # years $B^{Aobs}_y < B^A_{crit}$ consecutively	-	2.3	-	2.7	2.4	2.5	2.4	2.4	2.4	2.6
p(B_{sa}r+B_{anch}) < historical min	0.01	0.07	0.09	0.36	0.34	0.33	0.30	0.31	0.32	0.32
p($B_{sarwest}$+B_{anch}) < historical min			0.03	0.21	0.18	0.18	0.14	0.15	0.17	0.16

[6] This gives the median and 90%ile of the 1000 median (over 20 years for each simulation) catches.

[7] Catch statistics calculated over 2021 to 2023 only.

[8] Median and 90%ile of $AAV^b_y = \left|C^{S,b}_{tot,y} - C^{S,b}_{tot,y-1}\right| / C^{S,b}_{tot,y-1}$

Table 2. Key summary performance statistics assuming the alternative 'upper recruitment extreme' anchovy OM for a no catch scenario, OMP-18, OMP-14, and a CMP tuned to the same risk level as OMP-14: "CMP8", in addition to CMP3 and CMP4 from Table 1. Note that this is not a typical sensitivity test as it simply rejects 500 samples from the output prior to performance statistics being calculated; additionally not all performance statistics are easily adjusted and thus only some are reported here. The first columns additionally show the performance statistics under a no catch scenario, CMP3 and CMP4 assuming A_{BH}. Where appropriate, medians and 90% probability intervals are provided, and for some statistics the means are provided additionally and shown in **bold**. All biomasses are given in thousands of tons.

	A_{BH}			'Upper recruitment extreme'					
	No Catch	CMP3	CMP4	No Catch	OMP-18	OMP-14	CMP8	CMP3	CMP4
β	-	0.124	0.124	-	0.124	0.0869	0.124	0.124	0.124
α	-	0.936	0.936	-	1.16	0.889	0.955	0.936	0.936
$Risk_S$	0.061	0.224	0.222	0.060	0.226	0.210	0.224	0.223	0.222
$Risk_A$	0.030	0.181	0.140	0.014	0.163	0.137	0.136	0.133	0.101
$B_{2036}^{sp,A}$ or $B_{2040}^{sp,A}$	**2920** 2344 [654,7178]	**1890** 1254 [182,5896]	**1984** 1330 [265,6139]	2958 2435 [684,7231]	1856 1195 [152,6243]	1821 1205 [193,6187]	1929 1281 [188,6379]	**1938** 1286 [189,6385]	**2022** 1370 [279,6462]
$B_{2036}^{sp,A}/B_{2019}^{sp,A}$ or $B_{2040}^{sp,A}/B_{2019}^{sp,A}$	1.9 [0.4,8.7]	1.0 [0.1,6.4]	1.1 [0.1,6.7]	1.3 [0.3,4.6]	0.6 [0.1,3.5]	0.6 [0.1,3.4]	0.7 [0.1,3.5]	0.7 [0.1,3.5]	0.7 [0.1,3.8]
$B_{2036}^{sp,A}/B_{1996}^{sp,A}$ or $B_{2040}^{sp,A}/B_{1996}^{sp,A}$	5.0 [1.4,15.7]	2.6 [0.4,12.6]	2.8 [0.5,12.7]	5.1 [1.5,15.8]	2.5 [0.4,12.6]	2.5 [0.5,12.2]	2.6 [0.5,12.7]	2.7 [0.5,12.7]	3.0 [0.6,12.8]
$B_{2036}^{sp,A}/K^A$ or $B_{2040}^{sp,A}/K^A$	0.7 [0.2,2.0]	0.4 [0.0,1.6]	0.4 [0.1,1.7]	0.7 [0.2,1.9]	0.4 [0.0,1.6]	0.4 [0.0,1.6]	0.4 [0.1,1.6]	0.4 [0.1,1.7]	0.4 [0.1,1.7]
C^A	**0** 0 [0,0]	**274** 350 [11,350]	**270** 350 [7,350]	**0** 0 [0,0]	**296** 350 [190,350]	**329** 376 [188,450]	**289** 350 [194,350]	**288** 350 [192,350]	**285** 350 [183,350]
MAV^A [9]	-	0.12 [0.00,0.76]	0.13 [0.00,0.80]	-	0.00 [0.00,0.56]	0.22 [0.00,0.58]	0.08 [0.00,0.48]	0.09 [0.00,0.48]	0.09 [0.00,0.53]
$p(B_y^{Aobs} < B_{crit}^A, B_y < B_{crit}^A/k_N^A)$	-	0.19	0.26	-	0.16	0.14	0.14	0.13	0.20
$p(B_y^{Aobs} < B_{crit}^A, B_y \geq B_{crit}^A/k_N^A)$	-	0.03	0.04	-	0.02	0.03	0.02	0.02	0.04
$p(B_y^{Aobs} \geq B_{crit}^A, B_y < B_{crit}^A/k_N^A)$	-	0.02	0.04	-	0.02	0.02	0.02	0.02	0.03
$p(B_y^{Aobs} \geq B_{crit}^A, B_y \geq B_{crit}^A/k_N^A)$	-	0.76	0.66	-	0.79	0.81	0.82	0.82	0.73
Avg # years $B_y^{Aobs} < B_{crit}^A$ consecutively	-	2.5	2.4	-	2.5	2.2	2.3	2.3	2.3
$p(B_{sa}r+B_{anch})$ < historical min	0.09	0.33	0.30	0.06	0.30	0.29	0.28	0.28	0.02
$p(B_{sarwest}+B_{anch})$ < historical min	0.03	0.18	0.14	0.02	0.16	0.14	0.14	0.13	0.11

[9] Median and 90%ile of $AAV_y^b = \left|C_{tot,y}^{S,b} - C_{tot,y-1}^{S,b}\right| / C_{tot,y-1}^{S,b}$

Table 3. Key summary performance statistics for CMP3 and CMP4 assuming the baseline OM of A_{BH} and alternative CMPs where the maximum anchovy TAC is set at 275 000t instead of 350 000t. Where appropriate, medians and 90% probability intervals are provided, and for some statistics the means are provided additionally and shown in **bold**. All biomasses are given in thousands of tons.

	CMP3	CMP4	CMP3*	CMP4*
β	0.124	0.124	0.124	0.124
α	0.936	0.936	0.936	0.936
$Risk_S$	0.224	0.222	0.221	0.219
$Risk_A$	0.181	0.140	0.161	0.123
$p(B_{2020}^{sp,A} < B_{1996}^{sp,A})$	0.08	0.08	0.08	0.08
$p(B_{2021}^{sp,A} < B_{1996}^{sp,A})$	0.14 (+6)	0.12 (+4)	0.14 (+6)	0.12 (+4)
$p(B_{2022}^{sp,A} < B_{1996}^{sp,A})$	0.15 (+10)	0.13 (+8)	0.14 (+9)	0.12 (+7)
$p(B_{2023}^{sp,A} < B_{1996}^{sp,A})$	0.16 (+12)	0.12 (+8)	0.15 (+11)	0.11 (+7)
$p(B_{2024}^{sp,A} < B_{1996}^{sp,A})$	0.16 (+12)	0.13 (+9)	0.15 (+11)	0.11 (+7)
$B_{2036}^{sp,A}$ or $B_{2040}^{sp,A}$	**1890** 1254 [182,5896]	**1984** 1330 [265,6139]	**2047** 1449 [196,6084]	**2137** 1480 [290,6280]
$B_{2036}^{sp,A}/B_{2019}^{sp,A}$ or $B_{2040}^{sp,A}/B_{2019}^{sp,A}$	1.0 [0.1,6.4]	1.1 [0.1,6.7]	1.1 [0.1,6.9]	1.2 [0.2,7.0]
$B_{2036}^{sp,A}/B_{1996}^{sp,A}$ or $B_{2040}^{sp,A}/B_{1996}^{sp,A}$	2.6 [0.4,12.6]	2.8 [0.5,12.7]	3.0 [0.4,13.2]	3.1 [0.6,13.2]
$B_{2036}^{sp,A}/K^A$ or $B_{2040}^{sp,A}/K^A$	0.4 [0.0,1.6]	0.4 [0.1,1.7]	0.4 [0.1,1.7]	0.5 [0.1,1.7]
$B_{min}^{sp,A}$	350 [77,1094]	409 [115,1094]	393 [79,1229]	437 [121,1229]
$B_{min}^{sp,A}/B_{1996}^{sp,A}$	0.71 [0.16,2.52]	0.84 [0.25,2.52]	0.79 [0.16,2.77]	0.91 [0.26,2.77]
$B_{min}^{sp,A}/K^A$	0.11 [0.02,0.33]	0.13 [0.03,0.34]	0.12 [0.02,0.35]	0.14 [0.03,0.35]
C^A	**274** 350 [11,350]	**270** 350 [7,350]	**233** 275 [15,275]	**229** 275 [10,275]
Med C^A	349 [74,350]	350 [61,350]	275 [94,275]	275 [73,275]
C_{now}^A	350 [34,350]	350 [15,350]	275 [34,275]	275 [15,275]
MAV^A	0.12 [0.00,0.76]	0.13 [0.00,0.80]	0.00 [0.00,0.61]	0.00 [0.00,0.75]
$p(B_y^{Aobs} < B_{crit}^A, B_y < B_{crit}^A/k_N^A)$	0.19	0.26	0.17	0.23
$p(B_y^{Aobs} < B_{crit}^A, B_y \geq B_{crit}^A/k_N^A)$	0.03	0.04	0.03	0.04
$p(B_y^{Aobs} \geq B_{crit}^A, B_y < B_{crit}^A/k_N^A)$	0.02	0.04	0.02	0.03
$p(B_y^{Aobs} \geq B_{crit}^A, B_y \geq B_{crit}^A/k_N^A)$	0.76	0.66	0.79	0.69
Avg # years $B_y^{Aobs} < B_{crit}^A$ consecutively	2.5	2.4	2.5	2.3
p(B_{sar}+B_{anch}) < historical min	0.33	0.30	0.30	0.27
p($B_{sarwest}$+B_{anch}) < historical min	0.18	0.14	0.16	0.13

Table 4. Key summary performance statistics for CMP5 with $B_{crit}^{A} = 800$ under alternative anchovy OMs. The first column additionally shows the performance statistics under a no catch scenario using A_{BH}. Where appropriate, medians and 90% probability intervals are provided, and for some statistics the means are provided additionally and shown in **bold**. All biomasses are given in thousands of tons.

	No Catch	A_{BH}	A_{2BH}	A_{3BH}	A_{2BHrtn}	A_{R}	A_{HS}	A_{M1}	A_{M2}	A_{Mad}
$Risk_S$ under no catch		0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061
$Risk_A$ under no catch		0.030	0.028	0.082	0.036	0.052	<0.001	0.036	0.052	0.046
β		0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124
α		0.936	0.936	0.936	0.936	0.936	0.936	0.936	0.936	0.936
$Risk_S$	0.061	0.223	0.216	0.221	0.226	0.222	0.216	0.223	0.222	0.222
$Risk_A$	0.030	0.153	0.069	0.229	0.139	0.239	0.025	0.189	0.192	0.181
$p(B_{2020}^{sp,A} < B_{1996}^{sp,A})$	0.08	0.08	0.04	0.08	0.08	0.08	0.01	0.07	0.07	0.10
$p(B_{2021}^{sp,A} < B_{1996}^{sp,A})$	0.08	0.13	0.07	0.16	0.15	0.16	0.01	0.16	0.14	0.15
$p(B_{2022}^{sp,A} < B_{1996}^{sp,A})$	0.05	0.14	0.06	0.18	0.14	0.16	0.01	0.16	0.14	0.16
$p(B_{2023}^{sp,A} < B_{1996}^{sp,A})$	0.04	0.13	0.07	0.19	0.13	0.19	0.01	0.17	0.15	0.16
$p(B_{2024}^{sp,A} < B_{1996}^{sp,A})$	0.04	0.14	0.0.6	0.20	0.15	0.20	0.02	0.17	0.15	0.16
$B_{2036}^{sp,A}$	**2920** 2344	**1954** 1317	**4279** 3336	**1872** 1267	**1483** 1086	**1869** 1167	**2289** 2188	**2119** 1401	**1860** 1305	**2042** 1333
	[654,7178]	[228,5923]	[305,10477]	[74,6423]	[276,3958]	[117,5741]	[672,4028]	[251,6561]	[140,5773]	[186,6827]
$B_{2040}^{sp,A}/B_{2019}^{sp,A}$	1.9 [0.4,8.7]	1.0 [0.1,6.7]	1.6 [0.2,6.2]	0.9 [0.1,5.8]	1.0 [0.2,4.5]	0.8 [0.1,6.4]	1.3 [0.6,2.8]	1.1 [0.2,6.3]	1.0 [0.1,6.6]	1.1 [0.1,8.0]
$B_{2040}^{sp,A}/B_{1996}^{sp,A}$	5.0 [1.4,15.7]	2.7 [0.5,12.6]	7.1 [0.7,24.2]	2.5 [0.1,14.0]	2.2 [0.5,9.1]	2.4 [0.2,13.8]	4.5 [1.3,9.7]	2.4 [0.4,11.0]	2.6 [0.3,12.4]	2.7 [0.4,14.3]
$B_{2040}^{sp,A}/K^{A}$	0.7 [0.2,2.0]	0.4 [0.1,1.7]	0.8 [0.1,2.1]	0.4 [0.0,1.6]	0.5 [0.1,1.6]	0.3 [0.0,1.3]	0.8 [0.2,1.2]	0.4 [0.1,1.7]	0.4 [0.0,1.5]	0.4 [0.0,1.6]
$B_{min}^{sp,A}$	816 [263,1742]	390 [103,1094]	1090 [134,6297]	376 [35,1279]	358 [130,787]	307 [63,1322]	1421 [400,2330]	446 [132,1259]	376 [65,1125]	363 [84,1275]
$B_{min}^{sp,A}/B_{1996}^{sp,A}$	1.65 [0.55,4.06]	0.80 [0.22,2.52]	2.23 [0.03,1.01]	0.77 [0.07,3.00]	0.73 [0.25,1.72]	0.64 [0.13,2.99]	3.00 [0.81,5.72]	0.74 [0.21,2.35]	0.77 [0.13,2.60]	0.72 [0.16,2.62]
$B_{min}^{sp,A}/K^{A}$	0.25 [0.07,0.50]	0.12 [0.02,0.33]	0.27 [0.03,1.01]	0.14 [0.01,0.34]	0.17 [0.05,0.35]	0.08 [0.01,0.30]	0.53 [0.13,0.67]	0.13 [0.03,0.35]	0.11 [0.01,0.32]	0.11 [0.02,0.32]
C^{A}	**0** 0	**272** 350	**314** 350	**248** 330	**260** 305	**245** 324	**328** 350	**269** 343	**260** 349	**268** 350
	[0,0]	[8.350]	[49,350]	[0,350]	[16,350]	[0,350]	[223,350]	[12,350]	[1,350]	[5,350]
Med C^{A}	0 [0,0]	350 [66,350]	350 [118,350]	340 [0,350]	308 [115,350]	333 [12,350]	350 [249,350]	342 [81,350]	349 [18,350]	350 [58,350]
C_{now}^{A}	0 [0,0]	350 [20,350]	350 [70,350]	335 [7,350]	317 [26,350]	327 [7,350]	350 [239,350]	343 [27,350]	350 [14,350]	350 [14,350]
MAV^{A}	-	0.13 [0.00,0.79]	0.00 [0.00,0.57]	0.14 [0.00,0.90]	0.21 [0.00,0.79]	0.15 [0.00,0.95]	0.00 [0.00,0.29]	0.14 [0.00,0.81]	0.12 [0.00,0.88]	0.12 [0.00,0.79]
$p(B_y^{Aobs} < B_{crit}^{A}, B_y < B_{crit}^{A}/k_N^{A})$	-	0.23	0.10	0.30	0.28	0.32	0.04	0.22	0.27	0.25
$p(B_y^{Aobs} < B_{crit}^{A}, B_y \geq B_{crit}^{A}/k_N^{A})$	-	0.04	0.02	0.04	0.05	0.03	0.01	0.04	0.04	0.04
$p(B_y^{Aobs} \geq B_{crit}^{A}, B_y < B_{crit}^{A}/k_N^{A})$	-	0.03	0.01	0.03	0.05	0.03	0.01	0.03	0.03	0.03
$p(B_y^{Aobs} \geq B_{crit}^{A}, B_y \geq B_{crit}^{A}/k_N^{A})$	-	0.69	0.87	0.63	0.62	0.62	0.95	0.70	0.66	0.68
Avg # years	-	2.4	2.6	3.0	2.2	3.4	3.1	2.6	2.8	2.6
$B_y^{Aobs} < B_{crit}^{A}$ consecutively										
p(Bsar+Banch) < hist min	0.09	0.31	0.13	0.36	0.37	0.37	0.08	0.29	0.34	0.32
p(Bsarwest+Banch) < hist min	0.03	0.15	0.07	0.22	0.18	0.23	0.03	0.14	0.19	0.17

Table 4 (continued).

	No Catch	A_{BH}	A_{Mj}	A_{M2000+}	A_4	A_{DD}	A_{com2}	A_{kegg}	A_{lamR}	A_{lamN2}
$Risk_S$ under no catch		0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061
$Risk_A$ under no catch		0.030	0.034	0.032	0.033	0.049	0.033	0.034	0.019	0.030
β		0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124
α		0.936	0.936	0.936	0.936	0.936	0.936	0.936	0.936	0.936
$Risk_S$	0.061	0.223	0.223	0.220	0.222	0.225	0.223	0.222	0.224	0.222
$Risk_A$	0.030	0.153	0.146	0.157	0.155	0.178	0.165	0.146	0.119	0.155
$p(B_{2020}^{sp,A} < B_{1996}^{sp,A})$	0.08	0.08	0.06	0.02	0.07	0.06	0.06	0.06	0.01	0.06
$p(B_{2021}^{sp,A} < B_{1996}^{sp,A})$	0.08	0.13	0.10	0.05	0.13	0.12	0.15	0.11	0.05	0.12
$p(B_{2022}^{sp,A} < B_{1996}^{sp,A})$	0.05	0.14	0.12	0.07	0.12	0.12	0.13	0.11	0.07	0.12
$p(B_{2023}^{sp,A} < B_{1996}^{sp,A})$	0.04	0.13	0.12	0.09	0.12	0.13	0.14	0.13	0.07	0.13
$p(B_{2024}^{sp,A} < B_{1996}^{sp,A})$	0.04	0.14	0.14	0.11	0.14	0.14	0.14	0.11	0.10	0.14
$B_{2036}^{sp,A}$	**2920** 2344 [654,7178]	**1954** 1317 [228,5923]	**2061** 1427 [182,6009]	**1531** 1381 [133,3783]	**2005** 1334 [185,6151]	**1547** 1177 [187,4023]	**1999** 1384 [229,5944]	**2238** 1538 [234,6631]	**2087** 1509 [289,6092]	**2012** 1369 [225,6141]
$B_{2040}^{sp,A}/B_{2019}^{sp,A}$	1.9 [0.4,8.7]	1.0 [0.1,6.7]	1.1 [0.1,6.3]	0.9 [0.1,3.4]	1.1 [0.1,6.2]	0.9 [0.1,4.5]	1.1 [0.1,6.1]	1.1 [0.1,6.4]	0.8 [0.1,4.3]	1.1 [0.1,6.1]
$B_{2040}^{sp,A}/B_{1996}^{sp,A}$	5.0 [1.4,15.7]	2.7 [0.5,12.6]	3.1 [0.4,14.0]	2.9 [0.3,9.2]	2.8 [0.4,14.0]	2.4 [0.5,9.0]	2.7 [0.5,12.0]	3.0 [0.5,13.3]	2.9 [0.5,12.8]	2.8 [0.4,12.2]
$B_{2040}^{sp,A}/K^A$	0.7 [0.2,2.0]	0.4 [0.1,1.7]	0.4 [0.0,1.7]	0.5 [0.0,1.3]	0.4 [0.0,1.6]	0.1 [0.0,0.5]	0.4 [0.1,1.6]	0.4 [0.1,1.6]	0.4 [0.1,1.5]	0.4 [0.1,1.6]
$B_{min}^{sp,A}$	816 [263,1742]	390 [103,1094]	416 [91,1236]	673 [85,1465]	383 [83,1166]	367 [95,1043]	404 [108,1228]	443 [122,1273]	506 [144,1383]	396 [127,1186]
$B_{min}^{sp,A}/B_{1996}^{sp,A}$	1.65 [0.55,4.06]	0.80 [0.22,2.52]	0.90 [0.19,2.77]	1.43 [0.19,3.65]	0.81 [0.18,2.78]	0.77 [0.21,2.41]	0.80 [0.20,2.44]	0.84 [0.22,2.75]	1.01 [0.28,2.86]	0.79 [0.24,2.47]
$B_{min}^{sp,A}/K^A$	0.25 [0.07,0.50]	0.12 [0.02,0.33]	0.13 [0.02,0.35]	0.25 [0.03,0.52]	0.11 [0.02,0.31]	0.04 [0.01,0.12]	0.12 [0.03,0.33]	0.13 [0.03,0.33]	0.14 [0.04,0.36]	0.12 [0.03,0.32]
C^A	**0** 0 [0,0]	**272** 350 [8.350]	**273** 350 [7,350]	**277** 350 [3,350]	**271** 350 [6,350]	**262** 341 [5,350]	**272** 350 [9,350]	**275** 350 [11,350]	**279** 350 [19,350]	**272** 350 [11,350]
Med C^A	0 [0,0]	350 [66,350]	350 [49,350]	350 [11,350]	350 [42,350]	340 [65,350]	350 [70,350]	350 [77,350]	350 [113,350]	350 [73,350]
C_{now}^A	0 [0,0]	350 [20,350]	350 [25,350]	350 [51,350]	350 [22,350]	349 [21,350]	350 [27,350]	350 [25,350]	350 [57,350]	350 [24,350]
MAV^A	-	0.13 [0.00,0.79]	0.10 [0.00,0.84]	0.00 [0.00,0.90]	0.12 [0.00,0.81]	0.14 [0.00,0.86]	0.10 [0.00,0.79]	0.09 [0.00,0.76]	0.08 [0.00,0.73]	0.12 [0.00,0.81]
$p(B_y^{Aobs} < B_{crit}^A, B_y < B_{crit}^A/k_N^A)$	-	0.23	0.23	0.20	0.24	0.24	0.23	0.22	0.19	0.23
$p(B_y^{Aobs} < B_{crit}^A, B_y \geq B_{crit}^A/k_N^A)$	-	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04
$p(B_y^{Aobs} \geq B_{crit}^A, B_y < B_{crit}^A/k_N^A)$	-	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.04
$p(B_y^{Aobs} \geq B_{crit}^A, B_y \geq B_{crit}^A/k_N^A)$	-	0.69	0.70	0.74	0.69	0.68	0.70	0.71	0.74	0.69
Avg # years $B_y^{Aobs} < B_{crit}^A$ consecutively	-	2.4	2.5	3.4	2.5	2.6	2.6	2.5	2.4	2.4
p(Bsar+Banch) < hist min	0.09	0.31	0.30	0.28	0.32	0.33	0.30	0.27	0.27	0.31
p(Bsarwest+Banch) < hist min	0.03	0.15	0.16	0.14	0.16	0.17	0.16	0.13	0.12	0.16

Table 5. Key summary performance statistics for CMP6 with $B^A_{crit} = 700$ under alternative anchovy OMs. The first column additionally shows the performance statistics under a no catch scenario using A_{BH}. Where appropriate, medians and 90% probability intervals are provided, and for some statistics the means are provided additionally and shown in **bold**. All biomasses are given in thousands of tons.

	No Catch	A_{BH}	A_{2BH}	A_{3BH}	A_{2BHrtn}	A_R	A_{HS}	A_{M1}	A_{M2}	A_{Mad}
$Risk_S$ under no catch		0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061
$Risk_A$ under no catch		0.030	0.028	0.082	0.036	0.052	<0.001	0.036	0.052	0.046
β		0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124
α		0.936	0.936	0.936	0.936	0.936	0.936	0.936	0.936	0.936
$Risk_S$	0.061	0.224	0.217	0.222	0.227	0.223	0.216	0.224	0.222	0.223
$Risk_A$	0.030	0.167	0.074	0.243	0.184	0.261	0.031	0.205	0.209	0.197
$p\left(B^{sp,A}_{2020} < B^{sp,A}_{1996}\right)$	0.08	0.08	0.04	0.08	0.08	0.08	0.01	0.07	0.07	0.10
$p\left(B^{sp,A}_{2021} < B^{sp,A}_{1996}\right)$	0.08	0.14	0.07	0.16	0.15	0.16	0.01	0.17	0.14	0.15
$p\left(B^{sp,A}_{2022} < B^{sp,A}_{1996}\right)$	0.05	0.15	0.06	0.18	0.15	0.17	0.01	0.18	0.15	0.17
$p\left(B^{sp,A}_{2023} < B^{sp,A}_{1996}\right)$	0.04	0.14	0.07	0.20	0.15	0.20	0.02	0.18	0.16	0.17
$p\left(B^{sp,A}_{2024} < B^{sp,A}_{1996}\right)$	0.04	0.15	0.07	0.21	0.16	0.22	0.02	0.18	0.17	0.17
$B^{sp,A}_{2036}$	**2920** 2344 [654,7178]	**1923** 1287 [207,5910]	**4272** 3309 [279,10477]	**1844** 1235 [63,6423]	**1463** 1072 [246,3958]	**1816** 1152 [98,5740]	**2280** 2185 [572,4028]	**2086** 1378 [226,6508]	**1829** 1262 [121,5741]	**2010** 1309 [163,6784]
$B^{sp,A}_{2040}/B^{sp,A}_{2019}$	1.9 [0.4,8.7]	1.0 [0.1,6.5]	1.6 [0.2,6.0]	0.9 [0.0,5.6]	0.9 [0.2,4.4]	0.8 [0.1,6.4]	1.3 [0.5,2.8]	1.0 [0.1,6.3]	0.9 [0.1,6.6]	1.0 [0.1,7.9]
$B^{sp,A}_{2040}/B^{sp,A}_{1996}$	5.0 [1.4,15.7]	2.7 [0.4,12.7]	7.1 [0.6,24.2]	2.4 [0.1,13.9]	2.1 [0.4,8.9]	2.3 [0.2,13.7]	4.5 [1.2,9.7]	2.3 [0.3,11.0]	2.5 [0.2,12.3]	2.6 [0.3,14.3]
$B^{sp,A}_{2040}/K^A$	0.7 [0.2,2.0]	0.4 [0.1,1.7]	0.8 [0.1,2.1]	0.4 [0.0,1.6]	0.5 [0.1,1.6]	0.3 [0.0,1.3]	0.8 [0.2,1.2]	0.4 [0.1,1.7]	0.4 [0.0,1.5]	0.4 [0.0,1.6]
$B^{sp,A}_{min}$	816 [263,1742]	370 [90,1094]	1094 [118,6297]	361 [29,1279]	343 [117,787]	279 [54,1322]	1422 [335,2330]	427 [114,1259]	350 [56,1126]	341 [75,1278]
$B^{sp,A}_{min}/B^{sp,A}_{1996}$	1.65 [0.55,4.06]	0.76 [0.19,2.52]	2.23 [0.25,13.4]	0.72 [0.06,3.00]	0.69 [0.23,1.71]	0.58 [0.11,2.99]	3.00 [0.73,5.72]	0.70 [0.19,2.34]	0.73 [0.12,2.60]	0.68 [0.15,2.60]
$B^{sp,A}_{min}/K^A$	0.25 [0.07,0.50]	0.11 [0.02,0.33]	0.26 [0.03,1.01]	0.13 [0.01,0.34]	0.16 [0.04,0.34]	0.07 [0.01,0.30]	0.53 [0.11,0.67]	0.13 [0.03,0.35]	0.10 [0.01,0.32]	0.10 [0.02,0.32]
C^A	**0** 0 [0,0]	**273** 350 [10,350]	**314** 350 [57,350]	**250** 327 [0,350]	**263** 303 [20,350]	**245** 318 [0,350]	**328** 350 [218,350]	**271** 340 [14,350]	**261** 345 [1,350]	**269** 350 [6,350]
Med C^A	0 [0,0]	349 [69,350]	350 [143,350]	339 [0,350]	307 [126,350]	327 [13,350]	350 [237,350]	341 [88,350]	348 [17,350]	350 [59,350]
C^A_{now}	0 [0,0]	350 [25,350]	350 [96,350]	335 [9,350]	315 [35,350]	324 [9,350]	350 [237,350]	342 [33,350]	350 [19,350]	350 [18,350]
MAV^A	-	0.12 [0.00,0.76]	0.00 [0.00,0.51]	0.13 [0.00,0.92]	0.20 [0.00,0.77]	0.15 [0.00,0.94]	0.00 [0.00,0.29]	0.13 [0.00,0.79]	0.12 [0.00,0.88]	0.11 [0.00,0.77]
$p\left(B^{Aobs}_y < B^A_{crit}, B_y < B^A_{crit}/k^A_N\right)$	-	0.21	0.09	0.28	0.24	0.30	0.04	0.19	0.24	0.22
$p\left(B^{Aobs}_y < B^A_{crit}, B_y \geq B^A_{crit}/k^A_N\right)$	-	0.03	0.01	0.03	0.05	0.03	0.01	0.04	0.03	0.03
$p\left(B^{Aobs}_y \geq B^A_{crit}, B_y < B^A_{crit}/k^A_N\right)$	-	0.03	0.01	0.03	0.04	0.03	0.01	0.03	0.03	0.03
$p\left(B^{Aobs}_y \geq B^A_{crit}, B_y \geq B^A_{crit}/k^A_N\right)$	-	0.73	0.89	0.66	0.67	0.64	0.95	0.74	0.69	0.71
Avg # years $B^{Aobs}_y < B^A_{crit}$ consecutively	-	2.4	2.7	3.2	2.2	3.5	3.5	2.5	2.9	2.7
p(Bsar+Banch) < hist min	0.09	0.32	0.14	0.37	0.38	0.38	0.08	0.30	0.35	0.33
p(Bsarwest+Banch) < hist min	0.03	0.17	0.08	0.23	0.19	0.25	0.03	0.15	0.20	0.18

Table 5 (continued).

	No Catch	A_{BH}	A_{Mj}	A_{M2000+}	A_4	A_{DD}	A_{com2}	A_{kegg}	A_{lamR}	A_{lamN2}
$Risk_S$ under no catch		0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061
$Risk_A$ under no catch		0.030	0.034	0.032	0.033	0.049	0.033	0.034	0.019	0.030
β		0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124
α		0.936	0.936	0.936	0.936	0.936	0.936	0.936	0.936	0.936
$Risk_S$	0.061	0.224	0.224	0.221	0.223	0.226	0.224	0.223	0.224	0.223
$Risk_A$	0.030	0.167	0.158	0.169	0.170	0.194	0.178	0.159	0.135	0.170
$p\left(B_{2020}^{sp,A} < B_{1996}^{sp,A}\right)$	0.08	0.08	0.06	0.02	0.07	0.06	0.06	0.06	0.01	0.06
$p\left(B_{2021}^{sp,A} < B_{1996}^{sp,A}\right)$	0.08	0.14	0.11	0.05	0.13	0.12	0.15	0.11	0.06	0.13
$p\left(B_{2022}^{sp,A} < B_{1996}^{sp,A}\right)$	0.05	0.15	0.12	0.08	0.13	0.12	0.14	0.13	0.07	0.13
$p\left(B_{2023}^{sp,A} < B_{1996}^{sp,A}\right)$	0.04	0.14	0.13	0.09	0.13	0.14	0.15	0.14	0.08	0.15
$p\left(B_{2024}^{sp,A} < B_{1996}^{sp,A}\right)$	0.04	0.15	0.14	0.12	0.15	0.15	0.15	0.13	0.11	0.15
$B_{2036}^{sp,A}$	**2920** 2344 [654,7178]	**1923** 1287 [207,5910]	**2036** 1402 [155,6009]	**1514** 1376 [110,3783]	**1971** 1302 [161,6146]	**1521** 1150 [161,4000]	**1969** 1368 [204,5901]	**2209** 1521 [209,6631]	**2058** 1484 [250,6091]	**1983** 1322 [198,6111]
$B_{2040}^{sp,A}/B_{2019}^{sp,A}$	1.9 [0.4,8.7]	1.0 [0.1,6.5]	1.1 [0.1,6.3]	0.9 [0.1,3.4]	1.1 [0.1,6.2]	0.9 [0.1,4.5]	1.0 [0.1,5.9]	1.1 [0.1,6.3]	0.8 [0.1,4.3]	1.0 [0.1,6.0]
$B_{2040}^{sp,A}/B_{1996}^{sp,A}$	5.0 [1.4,15.7]	2.7 [0.4,12.7]	3.1 [0.3,13.9]	2.9 [0.2,9.2]	2.8 [0.3,14.0]	2.4 [0.4,9.0]	2.6 [0.4,12.0]	2.9 [0.4,13.2]	2.8 [0.5,12.7]	2.7 [0.4,12.2]
$B_{2040}^{sp,A}/K^A$	0.7 [0.2,2.0]	0.4 [0.1,1.7]	0.4 [0.0,1.7]	0.5 [0.0,1.3]	0.4 [0.0,1.6]	0.1 [0.0,0.5]	0.4 [0.1,1.6]	0.4 [0.0,1.6]	0.4 [0.1,1.5]	0.4 [0.1,1.6]
$B_{min}^{sp,A}$	816 [263,1742]	370 [90,1094]	399 [80,1236]	665 [70,1465]	366 [71,1166]	343 [84,1043]	383 [97,1228]	422 [106,1270]	483 [129,1383]	376 [111,1186]
$B_{min}^{sp,A}/B_{1996}^{sp,A}$	1.65 [0.55,4.06]	0.76 [0.19,2.52]	0.86 [0.17,2.79]	1.42 [0.16,3.65]	0.78 [0.16,2.76]	0.72 [0.17,2.41]	0.75 [0.18,2.44]	0.79 [0.19,2.75]	0.97 [0.25,2.86]	0.75 [0.22,2.47]
$B_{min}^{sp,A}/K^A$	0.25 [0.07,0.50]	0.11 [0.02,0.33]	0.12 [0.02,0.35]	0.25 [0.02,0.52]	0.11 [0.02,0.31]	0.04 [0.01,0.12]	0.11 [0.02,0.33]	0.12 [0.02,0.33]	0.13 [0.03,0.36]	0.11 [0.03,0.32]
C^A	**0** 0 [0,0]	**273** 350 [10,350]	**274** 350 [9,350]	**278** 350 [3,350]	**272** 350 [7,350]	**263** 336 [5,350]	**273** 350 [10,350]	**276** 350 [13,350]	**280** 350 [22,350]	**274** 350 [13,350]
Med C^A	0 [0,0]	349 [69,350]	350 [53,350]	350 [11,350]	350 [43,350]	336 [71,350]	350 [81,350]	350 [103,350]	350 [114,350]	350 [82,350]
C_{now}^A	0 [0,0]	350 [25,350]	350 [33,350]	350 [68,350]	350 [26,350]	348 [28,350]	350 [35,350]	350 [33,350]	350 [75,350]	350 [31,350]
MAV^A	-	0.12 [0.00,0.76]	0.10 [0.00,0.81]	0.00 [0.00,0.88]	0.11 [0.00,0.80]	0.13 [0.00,0.84]	0.10 [0.00,0.77]	0.09 [0.00,0.75]	0.07 [0.00,0.72]	0.12 [0.00,0.79]
$p\left(B_y^{Aobs} < B_{crit}^A, B_y < B_{crit}^A/k_N^A\right)$	-	0.21	0.20	0.19	0.21	0.22	0.21	0.19	0.17	0.21
$p\left(B_y^{Aobs} < B_{crit}^A, B_y \geq B_{crit}^A/k_N^A\right)$	-	0.03	0.03	0.03	0.03	0.04	0.03	0.04	0.03	0.04
$p\left(B_y^{Aobs} \geq B_{crit}^A, B_y < B_{crit}^A/k_N^A\right)$	-	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03
$p\left(B_y^{Aobs} \geq B_{crit}^A, B_y \geq B_{crit}^A/k_N^A\right)$	-	0.73	0.73	0.77	0.72	0.72	0.73	0.74	0.77	0.73
Avg # years $B_y^{Aobs} < B_{crit}^A$ consecutively	-	2.4	2.6	3.7	2.5	2.6	2.6	2.4	2.4	2.4
p(Bsar+Banch) < hist min	0.09	0.32	0.31	0.29	0.32	0.34	0.31	0.28	0.28	0.32
p(Bsarwest+Banch) < hist min	0.03	0.17	0.17	0.15	0.17	0.18	0.17	0.14	0.13	0.17

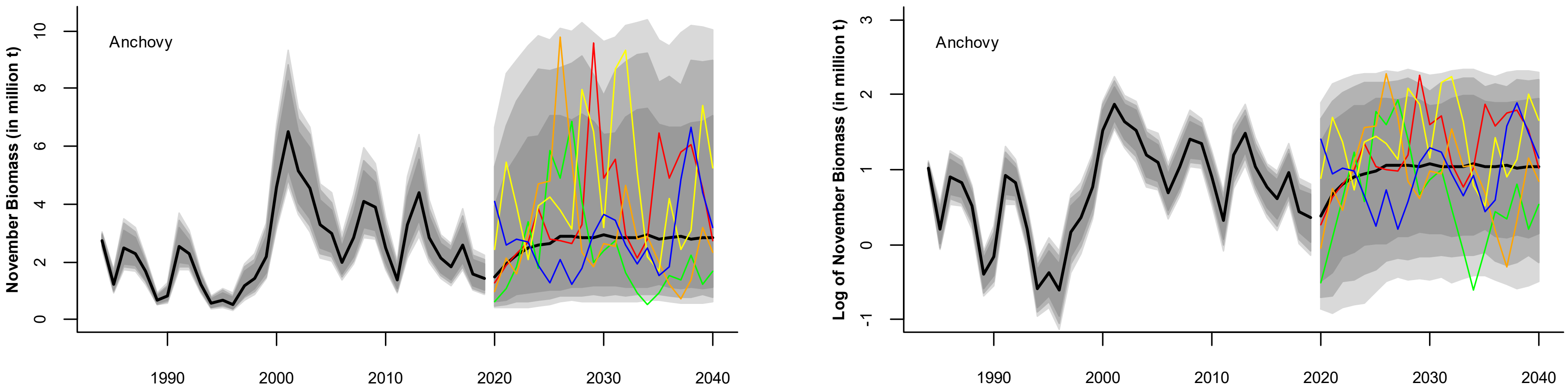


Figure 1. The historical anchovy November biomass and corresponding projected biomass under a no future catch scenario. Posterior medians are shown by the solid black line and the 80%ile, 90%ile and 95%ile by progressively lighter grey shading. The first five replicates are shown as example coloured 'worm plots'.

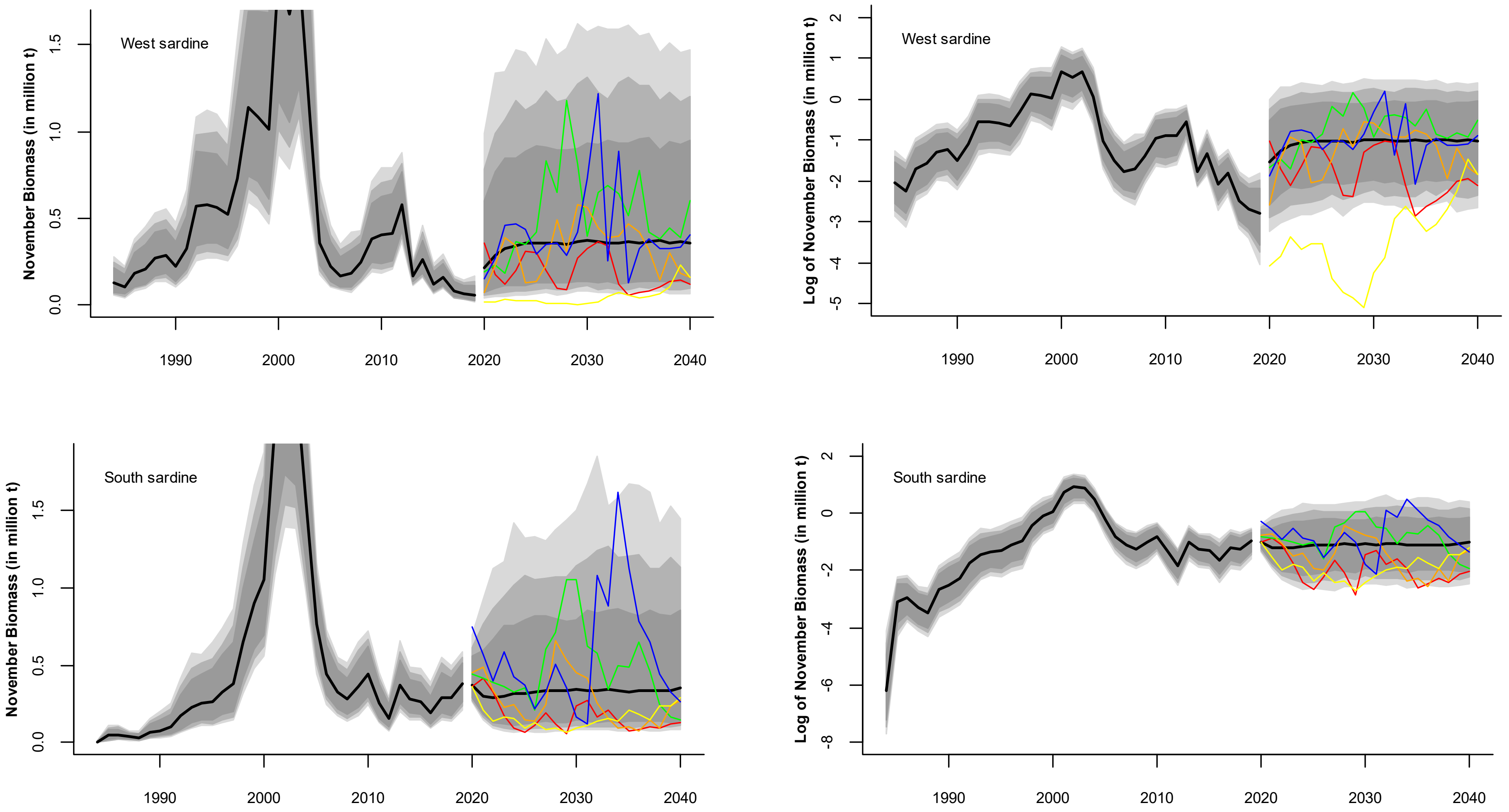


Figure 2. The historical sardine November biomass and corresponding projected biomass under a no future catch scenario. Posterior medians are shown by the solid black line and the 80%ile, 90%ile and 95%ile by progressively lighter grey shading. The first five replicates are shown as example coloured 'worm plots'.

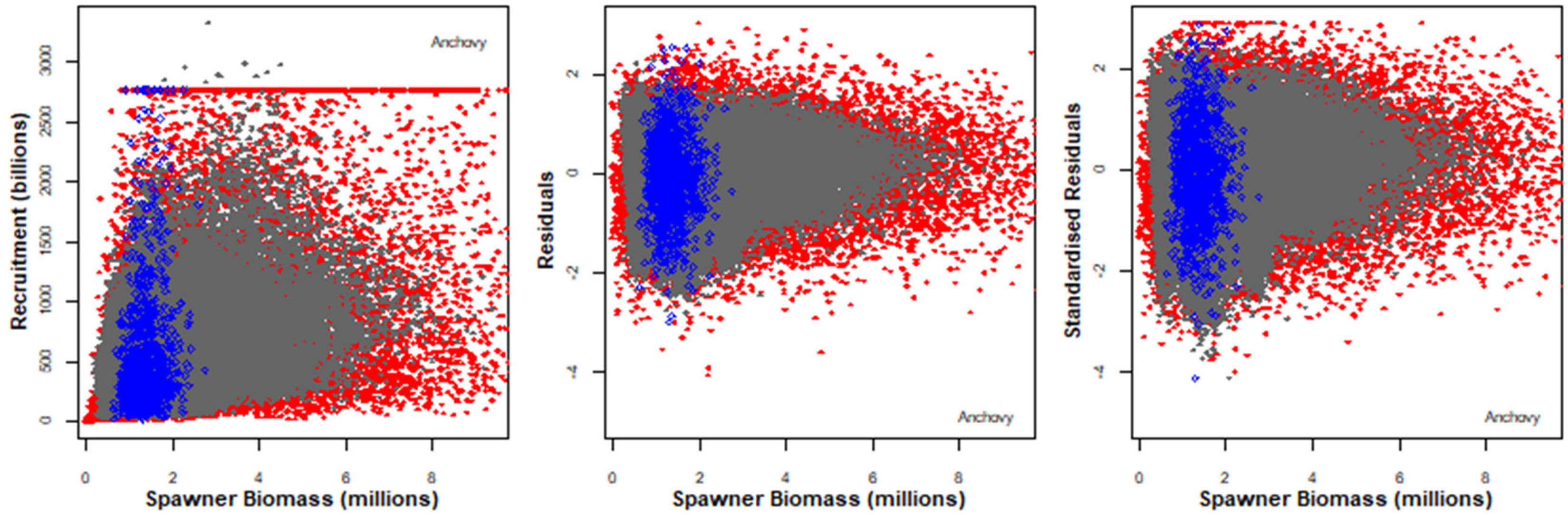


Figure 3. The historically estimated (grey) and future simulated (red, with blue showing November 2019) spawner biomass – recruitment pairs for anchovy (left). The residuals (middle) and standardised residuals (right) between these estimates and the estimated Beverton Holt stock recruitment relationship are also shown.

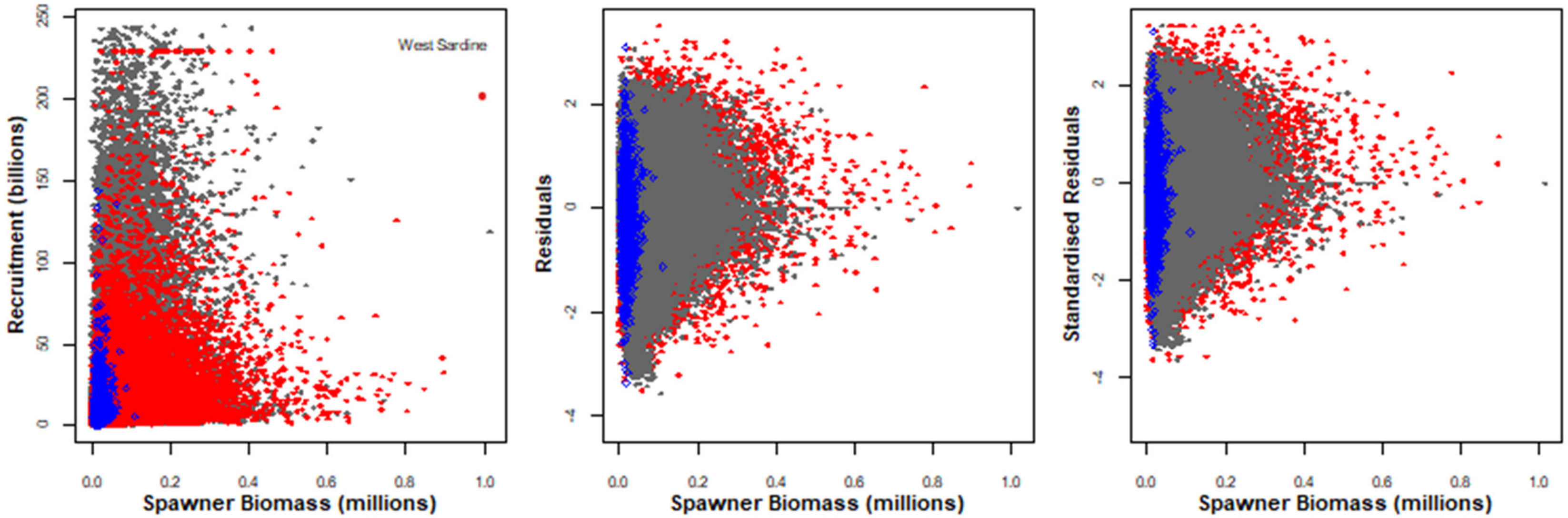
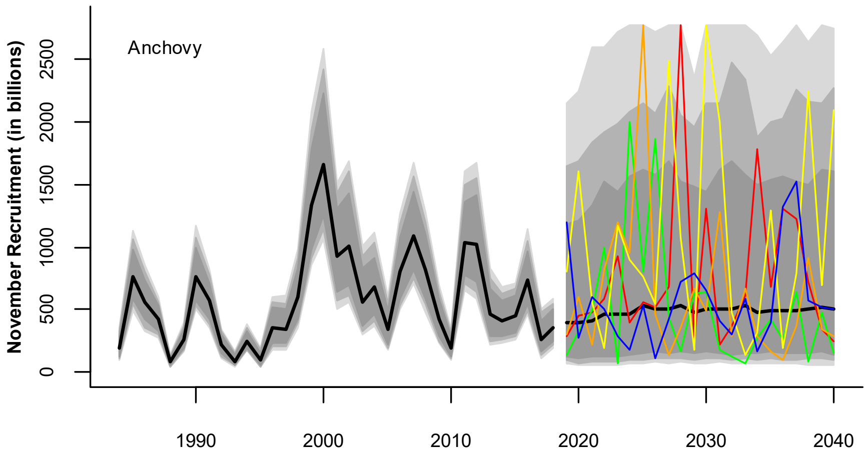


Figure 4. The historically estimated (right) and future simulated (red, with blue showing November 2019) spawner biomass – recruitment pairs for west component sardine (left). The residuals (middle) and standardised residuals (right) between these estimates and the estimated Hockey Stick stock recruitment relationship are also shown.



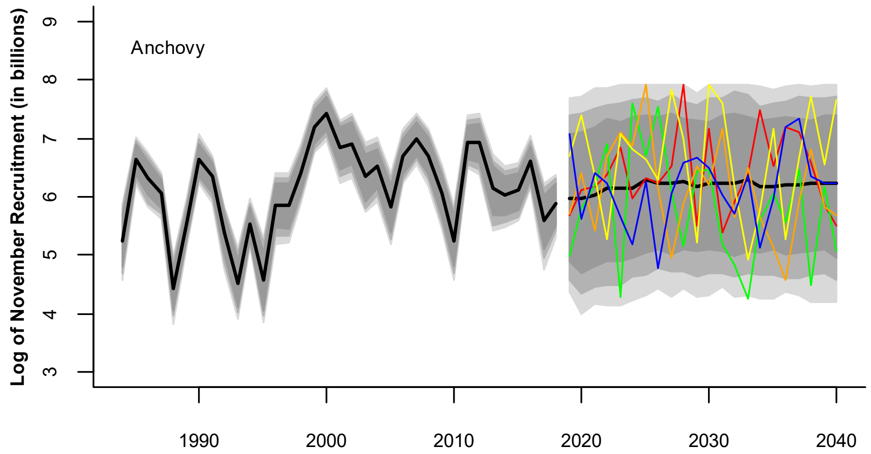


Figure 5. The historical anchovy November recruitment and corresponding projected recruitment under a no future catch scenario. Posterior medians are shown by the solid black line and the 80%ile, 90%ile and 95%ile by progressively lighter grey shading. The first five replicates are shown as example coloured 'worm plots'.

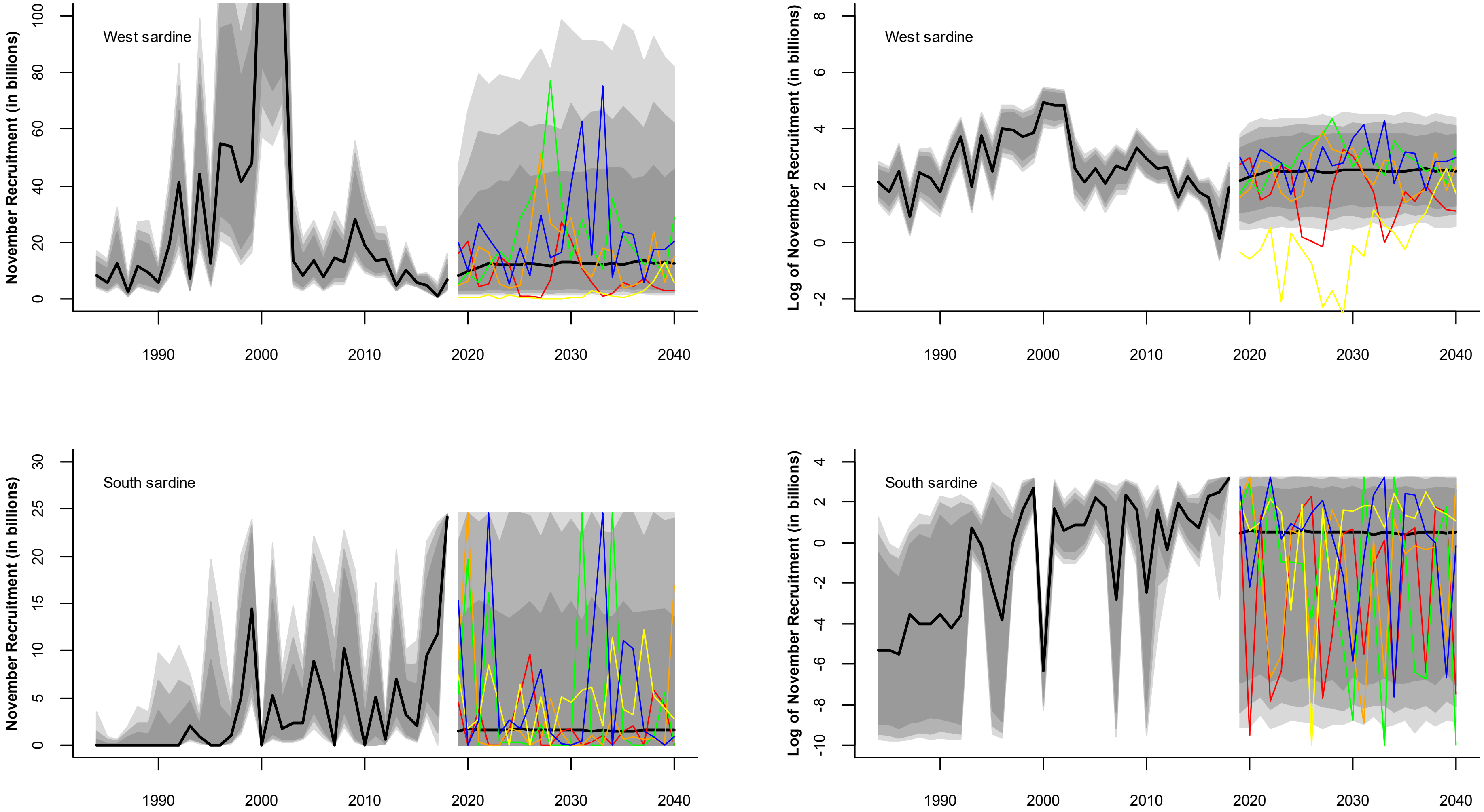


Figure 6. The historical sardine November recruitment and corresponding projected recruitment under a no future catch scenario. Posterior medians are shown by the solid black line and the 80%ile, 90%ile and 95%ile by progressively lighter grey shading. The first five replicates are shown as example coloured 'worm plots'.

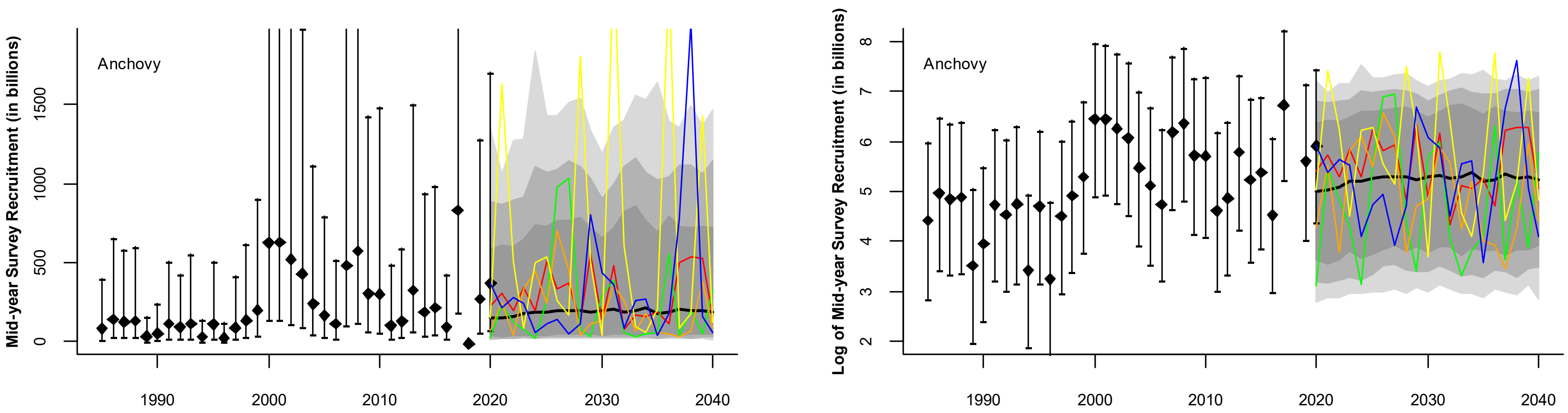


Figure 7. The historical anchovy survey estimates of recruitment (in May – July each year) and simulated future mid-May recruitment survey 'observations' under a no future catch scenario. Historical estimates are shown together with the 95% confidence interval taking survey CV and additional variance into account. For anchovy, additional variance differs by replicate; the median is used for this illustration. Posterior medians are shown by the solid black line and the 80%ile, 90%ile and 95%ile (taking survey CV and additional variance into account) by progressively lighter grey shading. The first five replicates are shown as example coloured 'worm plots'.

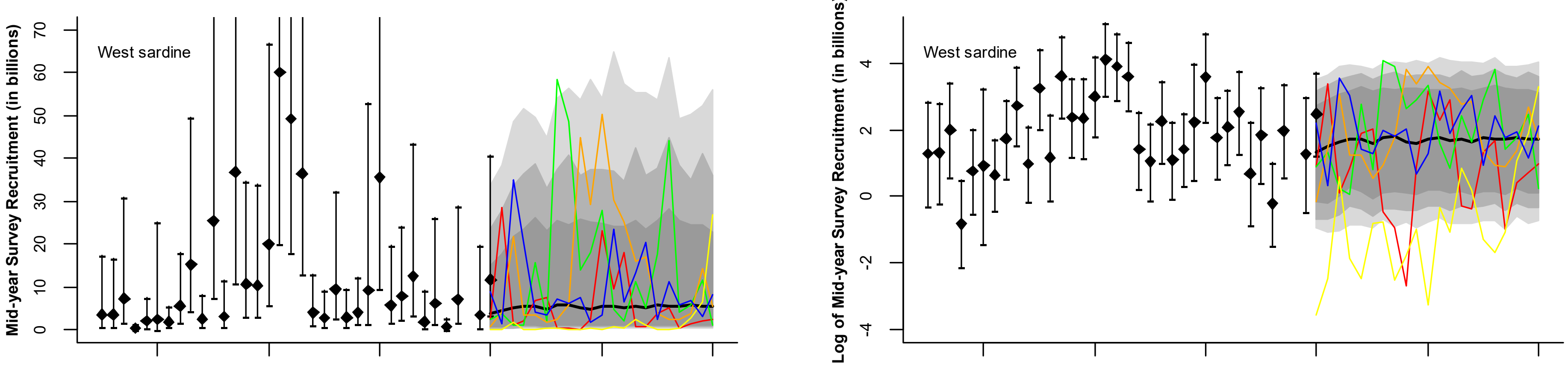


Figure 8. The historical sardine west component survey estimates of recruitment (in May – July each year) and simulated future mid-May recruitment survey 'observations' under a no future catch scenario. Historical estimates are shown together with the 95% confidence interval taking survey CV and additional variance into account. Posterior medians are shown by the solid black line and the 80%ile, 90%ile and 95%ile (taking survey CV and additional variance into account) by progressively lighter grey shading. The first five replicates are shown as example coloured 'worm plots'.

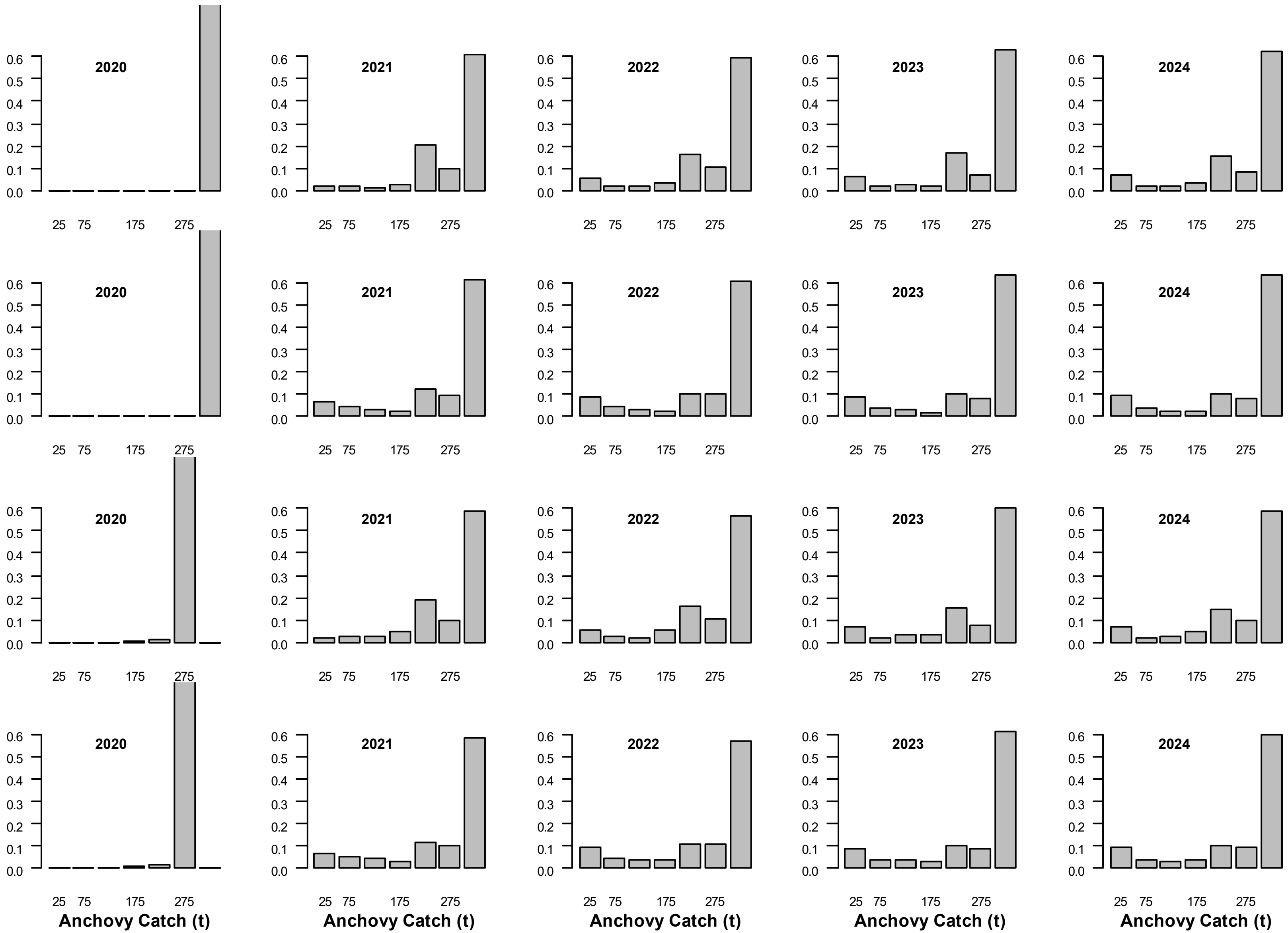


Figure 9. Histograms of annual final anchovy TAC for CMP3 (upper row) and CMP4 (second row) and realised anchovy catch for CMP3 (third row) and CMP4 (lower row) under A_{BH}.

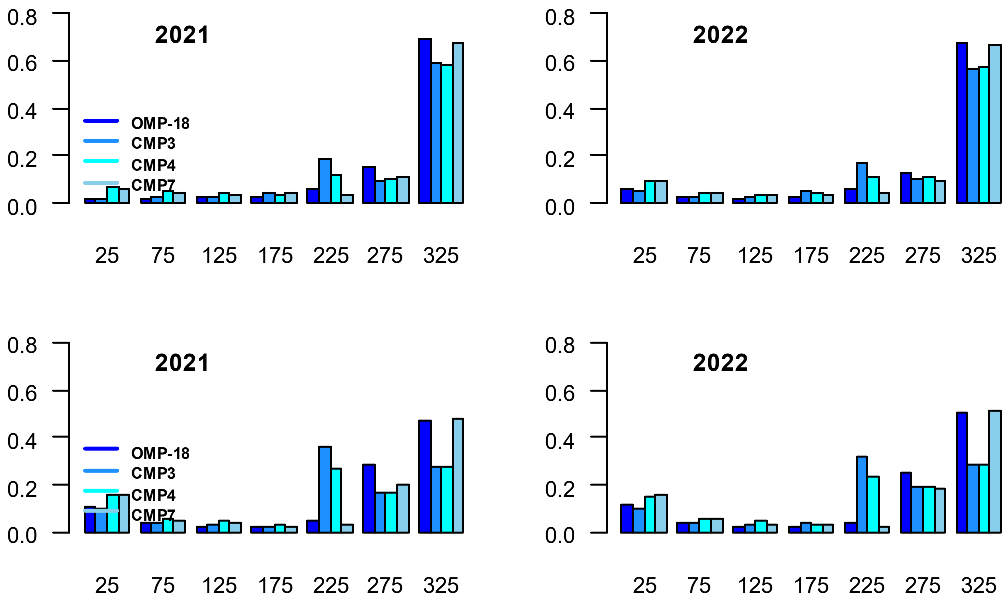


Figure 10. Histograms of realised anchovy catch (top row) and annual *initial* anchovy TAC (lower row) for OMP-18, CMP3, CMP4 and CMP7 under A_{BH}.

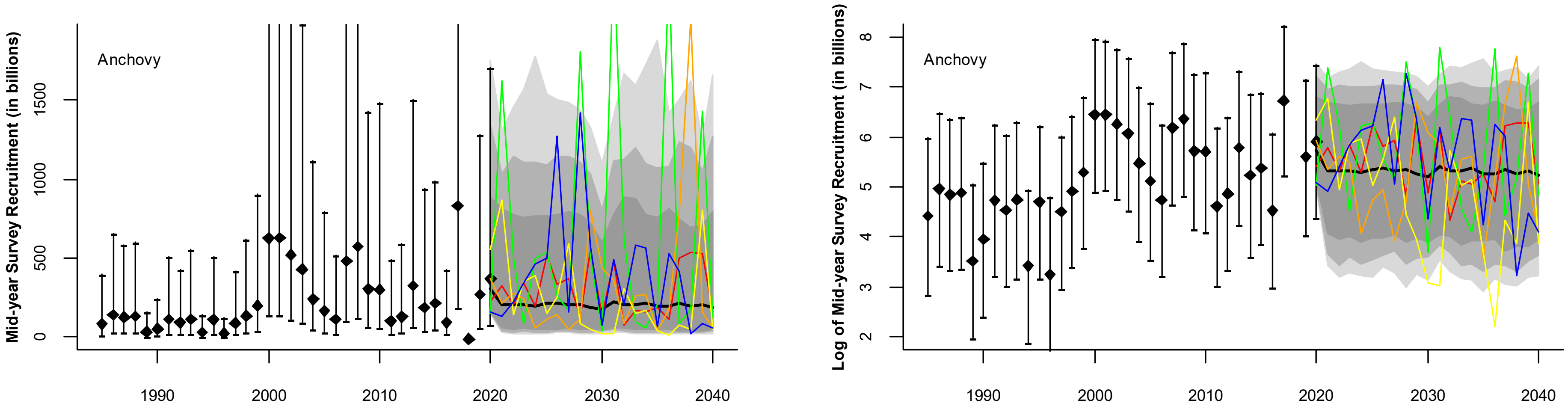


Figure 11. As per Figure 7, but for the ‘upper recruitment extreme’ scenario using only the top 500 recruitment simulations.

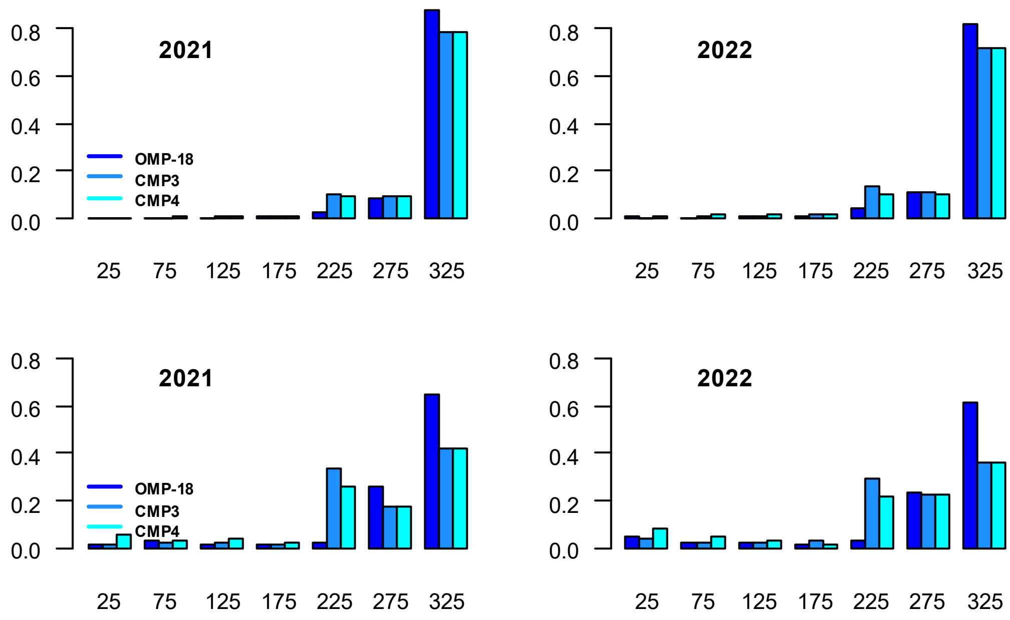


Figure 12. Histograms of realised anchovy catch (top row) and annual *initial* anchovy TAC (lower row) for OMP-18, CMP3 and CMP4 under the ‘upper recruitment extreme’.

Appendix A. Additional no future catch scenario figures

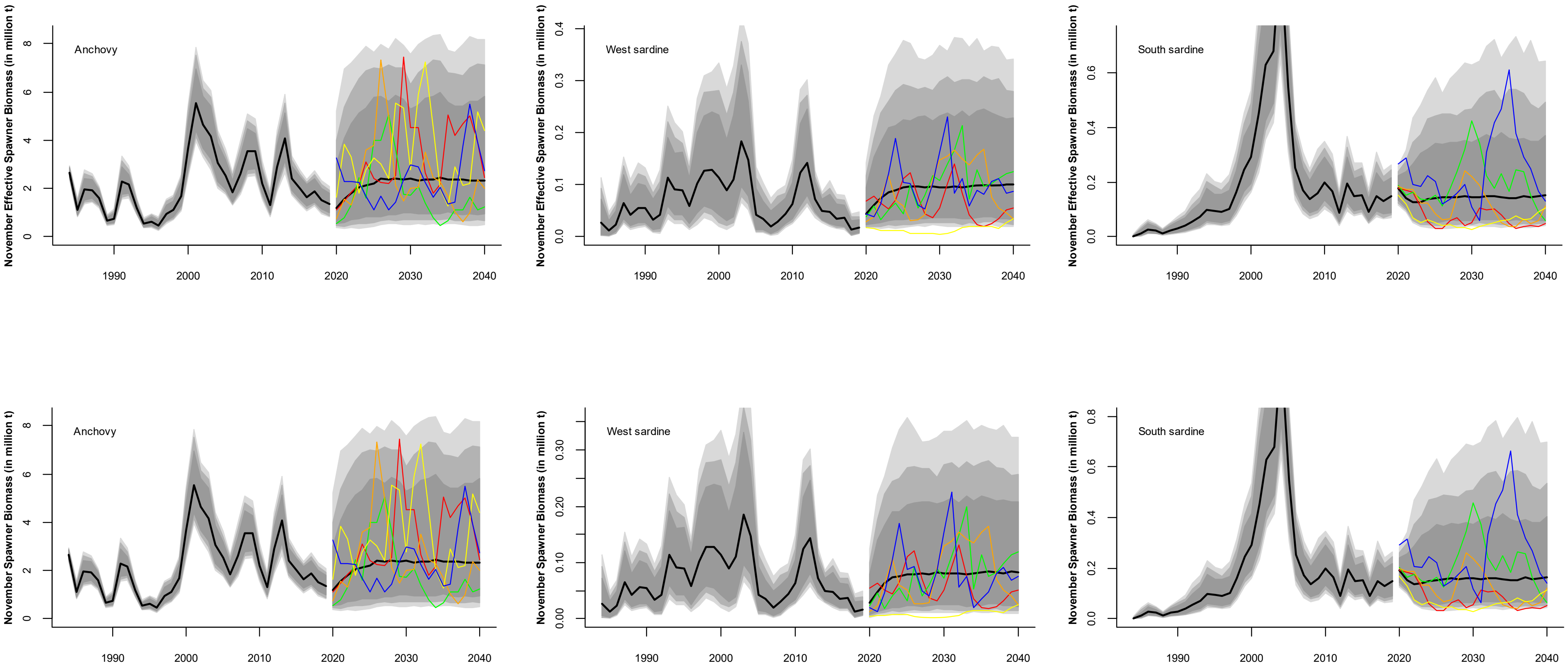


Figure A1. The historical November (effective) spawner biomass and corresponding projected (effective) spawner biomass under a no future catch scenario. For anchovy, there is no difference between spawner biomass and effective spawner biomass. For sardine, 8% of the south component spawner biomass contributes to west component effective spawner biomass. Posterior medians are shown by the solid black line and the 80%ile, 90%ile and 95%ile by progressively lighter grey shading. The first five replicates are shown as example coloured ‘worm plots’. Note the change in the vertical axis scale between figures.

Appendix B. Additional results when the anchovy catch in 2020 is subject to the same restrictions as all other future years, i.e. the anchovy catch in 2020 (i) could be reduced from the maximum TAC due to the simulated closure of the anchovy fishery in cases that the sardine bycatch with anchovy limit is reached and (ii) could reach amounts above 290 000t (given a TAC of 350 000t).

Table B1. Key summary performance statistics for a no catch scenario, OMP-18, OMP-14 and a CMP tuned to the same risk level as OMP-14: "CMP1", under A_{BH}. The first columns additionally show the performance statistics under a no catch scenario and OMP-18 using the OM available in 2018. All operating models assume the 2020 anchovy catch is subject to the same restrictions as all other years (i.e. a max TAC of 350 000t and closure of the anchovy fishery if the sardine TAB is simulated to be reached). Where appropriate, medians and 90% probability intervals are provided, and for some statistics the means are provided additionally and shown in **bold**. All biomasses are given in thousands of tons.

		OM based on data up to 2015		ABH, based on data up to 2019			
		No Catch	OMP-18	No Catch	OMP-18	OMP-14	CMP1
Risk statistics	β	-	0.124	-	0.124	0.0869	0.124
	α	-	1.16	-	1.16	0.889	0.940
	$Risk_S$	0.070	0.153	0.061	0.227	0.211	0.225
	$Risk_A$	0.018	0.089	0.027	0.214	0.178	0.178
Biomass statistics	$B_{2036}^{sp,A}$	**3384** 2341	**2669** 1613	**2921** 2344 [654,7183]	**1810** 1182 [133,5707]	**1784** 1154 [174,5575]	**1890** 1256 [181,5894]
	$B_{2036}^{sp,A}/B_{2015}^{sp,A}$ or $B_{2040}^{sp,A}/B_{2019}^{sp,A}$	1.6	1.1	1.9 [0.4,7.7]	0.9 [0.1,5.6]	0.9 [0.1,5.5]	0.9 [0.1,5.8]
	$B_{2036}^{sp,A}/B_{1996}^{sp,A}$ or $B_{2040}^{sp,A}/B_{1996}^{sp,A}$	4.9	3.4	5.0 [1.4,15.7]	2.4 [0.3,12.5]	2.4 [0.3,12.1]	2.6 [0.3,12.6]
	$B_{2036}^{sp,A}/K^A$ or $B_{2040}^{sp,A}/K^A$	1.2	0.9	0.7 [0.2,2.0]	0.4 [0.0,1.6]	0.4 [0.0,1.6]	0.4 [0.0,1.6]
	$B_{min}^{sp,A}$	920	543	843 [290,1742]	297 [64,1093]	341 [81,1025]	348 [77,1109]
	$B_{min}^{sp,A}/B_{1996}^{sp,A}$	2.0	1.2	1.7 [0.62,4.09]	0.62 [0.14,2.49]	0.69 [0.17,2.26]	0.72 [0.16,2.54]
	$B_{min}^{sp,A}/K^A$	0.5	0.3	0.25 [0.07,0.50]	0.09 [0.02,0.32]	0.10 [0.02,0.31]	0.11 [0.02,0.33]
Catch statistics	C^A	**11** 0	**311** 350	**0** 0 [0,0]	**282** 350 [5,350]	**312** 353 [83,450]	**275** 350 [92,350]
	Med C^A	0	350	0 [0,0]	350 [65,350]	355 [37,450]	350 [39,350]
	MAV^A	-	0.00	-	0.04 [0.00,0.86]	0.25 [0.00,0.80]	0.12 [0.00,0.73]
Critical Biomass statistics	$p(B_y^{Aobs} < B_{crit}^A, B_y < B_{crit}^A/k_N^A)$	-	0.07	-	0.21	0.18	0.18
	$p(B_y^{Aobs} < B_{crit}^A, B_y \geq B_{crit}^A/k_N^A)$	-	0.01	-	0.03	0.03	0.03
	$p(B_y^{Aobs} \geq B_{crit}^A, B_y < B_{crit}^A/k_N^A)$	-	0.01	-	0.03	0.03	0.02
	$p(B_y^{Aobs} \geq B_{crit}^A, B_y \geq B_{crit}^A/k_N^A)$	-	0.91	-	0.73	0.76	0.77
	Avg # years $B_y^{Aobs} < B_{crit}^A$ consecutively		2.3 yrs	-	2.8	2.4	2.6
Ecosystem statistics	P(Bsar+Banch) < historical min	0.01	0.07	0.09	0.35	0.34	0.33
				0.03	0.21	0.18	0.18

Table B2. Key summary performance statistics for CMP1 under alternative anchovy robustness tests. The first column additionally shows the performance statistics under a no catch scenario using A_{BH}. All operating models assume the 2020 anchovy catch is subject to the same restrictions as all other years (i.e. a max TAC of 350 000t and closure of the anchovy fishery if the sardine TAB is simulated to be reached). Where appropriate, medians and 90% probability intervals are provided, and for some statistics the means are provided additionally and shown in **bold**. All biomasses are given in thousands of tons.

	No Catch	A_{BH}	A_{2BH}	A_{3BH}	A_{2BHrtn}	A_{R}	A_{HS}	A_{M1}	A_{M2}	A_{Mad}
$Risk_S$ under no catch	0.061	0.061	0.061	0.062	0.061	0.061	0.061	0.061	0.061	0.061
$Risk_A$ under no catch	0.027	0.027	0.026	0.078	0.034	0.047	<0.001	0.035	0.047	0.044
β	-	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124
α	-	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
$Risk_S$	0.061	0.225	0.217	0.224	0.229	0.224	0.217	0.225	0.223	0.224
$Risk_A$	0.027	0.178	0.078	0.255	0.198	0.280	0.037	0.233	0.222	0.212
$p(B^{sp,A}_{2020} < B^{sp,A}_{1996})$	0.05	0.05	0.02	0.05	0.05	0.05	0.01	0.06	0.05	0.08
$p(B^{sp,A}_{2021} < B^{sp,A}_{1996})$	0.05	0.12	0.07	0.15	0.14	0.14	0.01	0.15	0.12	0.15
$p(B^{sp,A}_{2022} < B^{sp,A}_{1996})$	0.05	0.14	0.06	0.18	0.15	0.17	0.01	0.18	0.15	0.17
$p(B^{sp,A}_{2023} < B^{sp,A}_{1996})$	0.03	0.15	0.07	0.20	0.15	0.21	0.02	0.20	0.16	0.18
$p(B^{sp,A}_{2024} < B^{sp,A}_{1996})$	0.04	0.16	0.08	0.22	0.17	0.24	0.02	0.20	0.17	0.18
$B^{sp,A}_{2036}$	**2921** 2344 [654,7183]	**1890** 1256 [181,5894]	**4261** 3279 [255,10475]	**1812** 1196 [49,6253]	**1439** 1054 [218,3950]	**1753** 1069 [80,5615]	**2257** 2167 [435,3933]	**1978** 1274 [169,6379]	**1792** 1207 [98,5740]	**1964** 1285 [137,6650]
$B^{sp,A}_{2040}/B^{sp,A}_{2019}$	1.9 [0.4,7.7]	0.9 [0.1,5.8]	1.6 [0.2,5.3]	0.9 [0.0,5.0]	0.9 [0.1,4.2]	0.7 [0.1,5.9]	1.3 [0.4,2.7]	0.9 [0.1,5.8]	0.9 [0.1,5.6]	1.0 [0.1,7.0]
$B^{sp,A}_{2040}/B^{sp,A}_{1996}$	5.0 [1.4,15.7]	2.6 [0.3,12.6]	7.1 [0.6,24.2]	2.3 [0.1,13.8]	2.0 [0.4,8.9]	2.2 [0.2,13.0]	4.5 [1.0,9.7]	2.1 [0.3,10.8]	2.4 [0.2,12.3]	2.5 [0.3,14.2]
$B^{sp,A}_{2040}/K^A$	0.7 [0.2,2.0]	0.4 [0.0,1.6]	0.8 [0.1,2.1]	0.4 [0.0,1.6]	0.5 [0.1,1.6]	0.3 [0.0,1.3]	0.8 [0.1,1.2]	0.4 [0.0,1.6]	0.3 [0.0,1.5]	0.4 [0.0,1.6]
$B^{sp,A}_{min}$	843 [290,1742]	348 [77,1109]	1090 [104,6294]	346 [23,1287]	322 [98,787]	225 [44,1313]	1441 [283,2350]	382 [92,1204]	328 [48,1127]	320 [62,1256]
$B^{sp,A}_{min}/B^{sp,A}_{1996}$	1.7 [0.62,4.09]	0.72 [0.16,2.54]	2.23 [0.21,13.36]	0.69 [0.05,3.10]	0.65 [0.20,1.69]	0.53 [0.09,3.04]	2.99 [0.63,5.72]	0.62 [0.14,2.28]	0.68 [0.10,2.65]	0.64 [0.12,2.58]
$B^{sp,A}_{min}/K^A$	0.25 [0.07,0.50]	0.11 [0.02,0.33]	0.27 [0.03,1.01]	0.13 [0.00,0.34]	0.15 [0.04,0.34]	0.06 [0.01,0.30]	0.53 [0.10,0.67]	0.11 [0.02,0.34]	0.10 [0.01,0.32]	0.10 [0.01,0.32]
C^A	**0** 0 [0,0]	**275** 350 [12,350]	**315** 350 [71,350]	**252** 326 [0,350]	**266** 302 [25,350]	**246** 313 [0,350]	**328** 350 [215,350]	**268** 329 [12,350]	**263** 343 [1,350]	**270** 350 [7,350]
Med C^A	0 [0,0]	350 [92,350]	350 [154,350]	337 [0,350]	308 [138,350]	325 [12,350]	350 [221,350]	335 [82,350]	347 [18,350]	349 [55,350]
C^A_{now}	0 [0,0]	350 [39,350]	350 [138,350]	341 [14,350]	317 [54,350]	329 [17,350]	350 [241,350]	339 [46,350]	350 [32,350]	350 [30,350]
MAV^A	-	0.12 [0.00,0.73]	0.00 [0.00,0.46]	0.12 [0.00,0.89]	0.19 [0.00,0.69]	0.14 [0.00,0.95]	0.00 [0.00,0.29]	0.14 [0.00,0.79]	0.11 [0.00,0.86]	0.11 [0.00,0.72]
$p(B^{Aobs}_y < B^A_{crit}, B_y < B^A_{crit}/k^A_N)$	-	0.18	0.08	0.25	0.19	0.28	0.04	0.18	0.22	0.20
$p(B^{Aobs}_y < B^A_{crit}, B_y \geq B^A_{crit}/k^A_N)$	-	0.03	0.01	0.03	0.04	0.03	<0.01	0.03	0.03	0.03
$p(B^{Aobs}_y \geq B^A_{crit}, B_y < B^A_{crit}/k^A_N)$	-	0.02	0.01	0.02	0.04	0.03	0.01	0.03	0.02	0.02
$p(B^{Aobs}_y \geq B^A_{crit}, B_y \geq B^A_{crit}/k^A_N)$	-	0.77	0.90	0.70	0.73	0.67	0.95	0.76	0.73	0.75
Avg # years $B^{Aobs}_y < B^A_{crit}$ consecutively	-	2.6	3.0	3.6	2.2	3.7	4.0	2.7	3.1	2.8
p(Bsar+Banch) < hist min	0.09	0.33	0.14	0.38	0.39	0.39	0.08	0.33	0.36	0.34
p(Bsarwest+Banch) < hist min	0.03	0.18	0.08	0.24	0.20	0.26	0.04	0.18	0.21	0.20

Table B2 (continued).

	No Catch	A_{BH}	A_{Mj}	A_{M2000+}	A_4	A_{DD}	A_{com2}	A_{kegg}	A_{lamR}	A_{lamN2}
$Risk_S$ under no catch	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061
$Risk_A$ under no catch	0.027	0.027	0.032	0.030	0.026	0.047	0.030	0.031	0.018	0.027
β	-	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124
α	-	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
$Risk_S$	0.061	0.225	0.225	0.222	0.225	0.227	0.225	0.224	0.225	0.224
$Risk_A$	0.027	0.178	0.171	0.213	0.165	0.230	0.198	0.170	0.148	0.183
$p\left(B_{2020}^{sp,A} < B_{1996}^{sp,A}\right)$	0.05	0.05	0.04	0.02	0.04	0.04	0.05	0.04	0.00	0.04
$p\left(B_{2021}^{sp,A} < B_{1996}^{sp,A}\right)$	0.05	0.12	0.11	0.06	0.11	0.12	0.14	0.10	0.04	0.11
$p\left(B_{2022}^{sp,A} < B_{1996}^{sp,A}\right)$	0.05	0.14	0.13	0.09	0.12	0.14	0.15	0.12	0.07	0.13
$p\left(B_{2023}^{sp,A} < B_{1996}^{sp,A}\right)$	0.03	0.15	0.14	0.11	0.13	0.15	0.16	0.14	0.08	0.16
$p\left(B_{2024}^{sp,A} < B_{1996}^{sp,A}\right)$	0.04	0.16	0.15	0.14	0.13	0.18	0.16	0.14	0.11	0.16
$B_{2036}^{sp,A}$	**2921** 2344 [654,7183]	**1890** 1256 [181,5894]	**2003** 1364 [128,6005]	**1394** 1213 [79,3685]	**2008** 1337 [154,6221]	**1424** 1028 [124,3963]	**1898** 1302 [167,5748]	**2183** 1503 [172,6633]	**2035** 1448 [214,6097]	**1946** 1293 [166,6149]
$B_{2040}^{sp,A}/B_{2019}^{sp,A}$	1.9 [0.4,7.7]	0.9 [0.1,5.8]	1.0 [0.1,5.9]	0.8 [0.1,3.1]	1.1 [0.1,5.8]	0.8 [0.1,4.3]	0.9 [0.1,5.5]	1.0 [0.1,5.7]	0.8 [0.1,4.0]	0.9 [0.1,5.5]
$B_{2040}^{sp,A}/B_{1996}^{sp,A}$	5.0 [1.4,15.7]	2.6 [0.3,12.6]	3.0 [0.3,13.9]	2.5 [0.2,8.5]	2.8 [0.3,14.1]	2.2 [0.3,8.8]	2.5 [0.3,11.8]	2.9 [0.3,13.1]	2.8 [0.4,12.8]	2.6 [0.3,12.1]
$B_{2040}^{sp,A}/K^A$	0.7 [0.2,2.0]	0.4 [0.0,1.6]	0.4 [0.0,1.7]	0.5 [0.0,1.3]	0.4 [0.0,1.6]	0.1 [0.0,0.5]	0.4 [0.0,1.6]	0.4 [0.0,1.6]	0.4 [0.1,1.5]	0.4 [0.0,1.6]
$B_{min}^{sp,A}$	843 [290,1742]	348 [77,1109]	383 [65,1232]	590 [51,1381]	376 [75,1253]	294 [64,988]	351 [76,1200]	416 [89,1313]	476 [110,1388]	356 [91,1188]
$B_{min}^{sp,A}/B_{1996}^{sp,A}$	1.7 [0.62,4.09]	0.72 [0.16,2.54]	0.82 [0.15,2.80]	1.26 [0.11,3.50]	0.80 [0.16,2.93]	0.60 [0.13,2.32]	0.70 [0.15,2.38]	0.77 [0.17,2.73]	0.93 [0.21,2.91]	0.71 [0.18,2.46]
$B_{min}^{sp,A}/K^A$	0.25 [0.07,0.50]	0.11 [0.02,0.33]	0.12 [0.02,0.35]	0.22 [0.02,0.49]	0.11 [0.02,0.32]	0.04 [0.01,0.12]	0.11 [0.02,0.33]	0.12 [0.02,0.33]	0.13 [0.03,0.36]	0.11 [0.02,0.32]
C^A	**0** 0 [0,0]	**275** 350 [12,350]	**276** 350 [11,350]	**271** 350 [1,350]	**278** 350 [13,350]	**259** 323 [4,350]	**273** 350[10,350]	**279** 350 [17,350]	**282** 350 [27,350]	**275** 350 [15,350]
Med C^A	0 [0,0]	350 [92,350]	350 [64,350]	350 [8,350]	350 [67,350]	327 [57,350]	350 [66,350]	350 [109,350]	350 [120,350]	350 [83,350]
C_{now}^A	0 [0,0]	350 [39,350]	350 [49,350]	350 [74,350]	350 [60,350]	344 [34,350]	350 [51,350]	350 [52,350]	350 [118,350]	350 [49,350]
MAV^A	-	0.12 [0.00,0.73]	0.09 [0.00,0.80]	0.01 [0.01,0.91]	0.10 [0.00,0.70]	0.15 [0.00,0.86]	0.11 [0.00,0.76]	0.09 [0.00,0.69]	0.07 [0.00,0.67]	0.12 [0.00,0.79]
$p\left(B_y^{Aobs} < B_{crit}^A, B_y < B_{crit}^A/k_N^A\right)$	-	0.18	0.18	0.20	0.17		0.19	0.17	0.14	0.18
$p\left(B_y^{Aobs} < B_{crit}^A, B_y \geq B_{crit}^A/k_N^A\right)$	-	0.03	0.03	0.02	0.03		0.03	0.03	0.03	0.03
$p\left(B_y^{Aobs} \geq B_{crit}^A, B_y < B_{crit}^A/k_N^A\right)$	-	0.02	0.02	0.02	0.02		0.03	0.02	0.02	0.03
$p\left(B_y^{Aobs} \geq B_{crit}^A, B_y \geq B_{crit}^A/k_N^A\right)$	-	0.77	0.77	0.76	0.78		0.76	0.78	0.81	0.76
Avg # years $B_y^{Aobs} < B_{crit}^A$ consecutively	-	2.6	2.6	4.2	2.6		2.7	2.5	2.4	2.5
p(Bsar+Banch) < hist min	0.09	0.33	0.32	0.33	0.32		0.33	0.28	0.28	0.33
p(Bsarwest+Banch) < hist min	0.03	0.18	0.18	0.19	0.17		0.19	0.15	0.14	0.18