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YET FURTHER REFINEMENTS OF THE BR CMP

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SUMMARY

This paper seeks improved performance of CMP BR_6 (Butterworth and Rademeyer 2021) to avoid possible very low TACs for the East area. This can be improved somewhat by placing caps on the East area TAC for the next 10 years, with an upper cap of 36 000 mt (equal to the current TAC for this area) suggested. A further modification indicated for BR_6 is lessening the maximum downward TAC change possible from 50% to 30%, which does not increase resource risk markedly. Stochastic results for the resultant BR10 CMP show a few instances of extirpation of the eastern stock for R2 OMs, indicating a possible need for further refinement of this CMP. Given strong differences in especially east stock trajectory projections for the different recruitment (R) scenarios, presenting CMP results separately for each R scenario is suggested, rather than some weighted average across the three, to provide a more informative basis to compare performances across CMPs. Appendices provide mathematical specifications of the BR CMP and indications for sensitivity of BR10 performance statistics to tuning to weighted rather than unweighted OMs.

RÉSUMÉ

Ce document cherche à améliorer les performances de la CMP BR_6 (Butterworth et Rademeyer 2021) afin d'éviter d'éventuels TAC très bas pour la zone Est. Cette situation peut être améliorée quelque peu en imposant des plafonds au TAC de la zone Est pour les 10 prochaines années, un plafond supérieur de 36.000 t (égal au TAC actuel pour cette zone) étant suggéré. Une autre modification indiquée pour le BR_6 consiste à réduire la variation maximale à la baisse du TAC possible de 50% à 30%, ce qui n'augmente pas sensiblement le risque pour les ressources. Les résultats stochastiques de la CMP BR10 résultante montrent quelques cas de disparition du stock oriental pour des OM R2, ce qui indique la nécessité d'affiner encore cette CMP. Compte tenu des fortes différences, notamment dans les projections de la trajectoire du stock de l'Est pour les différents scénarios de recrutement (R), il est suggéré de présenter les résultats des CMP séparément pour chaque scénario R plutôt que sous la forme d'une moyenne pondérée des trois, afin de fournir une base plus informative pour comparer les performances des différentes CMP. Les appendices fournissent les spécifications mathématiques de la CMP BR et des indications sur la sensibilité des statistiques de performance du BR10 au calibrage avec des OM pondérés plutôt que non pondérés.

RESUMEN

Este trabajo busca mejorar el desempeño del CMP BR_6 (Butterworth y Rademeyer 2021) para evitar posibles TAC muy bajos para la zona este. Esto puede mejorarse en cierta medida estableciendo topes en el TAC de la zona este para los próximos 10 años, sugiriéndose un tope máximo de 36.000 t (igual al TAC actual para esta zona). Otra modificación indicada para BR_6 es la disminución del cambio máximo posible del TAC a la baja del 50 % al 30 %, lo que no aumenta notablemente el riesgo para los recursos. Los resultados estocásticos del CMP BR10 resultante muestran algunos casos de desaparición del stock oriental para R2 OM, lo que indica una posible necesidad de perfeccionamiento de este CMP. Dadas las grandes diferencias en las proyecciones de la trayectoria del stock oriental para los diferentes escenarios de reclutamiento (R), se sugiere presentar los resultados de los CMP por separado para cada escenario R, en lugar de como una media ponderada entre los tres, para proporcionar una base más informativa para comparar los resultados entre los CMP. Los apéndices proporcionan especificaciones matemáticas del CMP BR e indicaciones sobre la sensibilidad de las estadísticas del desempeño de BR10 a la calibración con los OM ponderados en lugar de con los no ponderados.

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KEYWORDS

Management Strategy Evaluation, Candidate Management Procedure, Operating Model grid, Atlantic bluefin tuna, development tuning

Introduction

Butterworth and Rademeyer (2021) presented the results for some refinements to the BR CMP. However, they also drew attention to a particular aspect of poor performance for their then best choice (BR_6) under R2 scenarios. This concerned the low 5%-ile for AvC30 for the East area of some 12kt (lower still if only R2 scenarios were considered). This low East area catch seemed unnecessary for the R2 scenarios for which Br30 values for the Eastern stock were above (and many well above) 1 for all the OMs concerned. The problem seemed to arise from the fact that at the start of CMP implementation, abundance decreased; **however** East area catches increased for a few years before being reduced dramatically. Nevertheless, it took time before the abundance trend for the Eastern stock, which had been driven to a low and less productive level, to reverse direction and eventually allow TACs in the East area to increase again back towards levels in the vicinity of 20 kt. Butterworth and Rademeyer (2021) identified improvement of this performance as a priority for further refinement of the BR CMP.

This document provides results for such an improvement to BR_6. During the January 2021 webinar, concerns were also expressed at the potentially large TAC reductions of up to 50% that could occur in some situations under the BR_6 rules. The consequences of lessening the size of this reduction are explored. Further investigations explore different (development) tunings for the western and eastern stocks, the impact of different post-2032 caps on the East area TAC; they also contrast stochastic compared to deterministic results for BR10 and the other development tunings for the western stock. Finally, the behaviours of East area abundance index projections for different recruitment scenarios are compared to provide insight into the reasons for the different results under the BR CMP for R1 vs R2 OMs.

Results

Results for several new BR CMP variants are presented. **Table 1** lists the BR CMP variants presented here, with their control parameter values.

BR_7 to BR_9 add different TAC bounds to those of BR_6 for the East area TAC for the first ten years (to 2032) of the CMP application. BR10 reduces the maximum downward extent of a TAC change of 50% allowed in BR_6 to 30%. The deterministic Br30 and AvC30 values (medians and 90%iles across the full interim grid of OMs) for each of the CMPs are given in **Table 2a**, first for all OMs, and then for each recruitment scenario separately.

BR10, the current “Base” CMP, is tuned to a median Br30 west of 1.00, while BR11 and BR12 are tuned to 1.25 and 1.50 respectively. The results for these three CMPs are given in **Table 2b**.

Figure 1 is a visual representation of the BR6 to BR12 results. The deterministic Br30 and AvC30 values under the BR_6 and new BR_7 CMPs for each of the 96 OMs of the interim grid are compared in **Figure 2.**

For BR13 to BR16, the α control parameter of the CMP which governs the East area TAC is varied from 0.5 to 5, with the “Base” CMP, BR10, having a value of 2. This results in a range of median Br30 east from 1.17 to 2.47. The results are given in **Table 2c**.

Finally, for BR17 to BR19, the post-2032 East area TAC cap is increased from 45 000t for the “Base” CMP to 60 000t for BR19. The results are given in **Table 2d**.

Figure 3 is visual representation of the BR13 to BR19 results.

Stochastic runs have been carried out for BR10, BR11 and BR12 (corresponding to the three median Br30 west tunings), and the results are shown **Table 3** and **Figure 4**, being contrasted to the comparative deterministic results in that Figure. **Figure 5** plots the stochastic Br30 and AvC30 values under BR10 for each of the 96 OMs of the interim grid. Five simulated catch and biomass trajectories for OM2 (R2, A, I, --, L) under BR10 are compared in **Figure 6.**

Figure 7 compares the catch and biomass projections for OM1, OM2 and OM3 under BR_6 and BR10, while **Figure 8** compares the upper and lower 5%iles catch and biomass projections for BR_6 and BR10 for each of the three recruitment scenarios.

Stochastic runs of OM1 and OM2 have been carried out under BR_7, and the resulting abundance index ratios for OM2 compared to OM1 are plotted in **Figure 9** as medians and 90%iles. Note that error terms (such as observation errors for abundance indices or stock-recruitment residuals) are the same for each pair of replicates used in computing these ratios. **Figure 10** shows the same ratios for each linked pair of OMs for the R2 and R1 scenarios in the interim grid, except that here deterministic projections are used and the medians and 90%iles refer to distributions of the ratio across the scenarios in the interim grid.

Discussion

The further East area TAC caps added for the BR_7 to BR_9 variants have a dual intent: the upper cap is to prevent unduly large TAC increases in the East area in the immediate future so as to ameliorate the extent of the subsequent TAC reduction needed shortly thereafter for R2 scenarios, while the lower cap is to avoid TACs being set lower than needed to still admit an adequate rate of resource recovery.

Of these three alternatives, BR_7 (which would preclude any increase in the current East area TAC of 36 000 mt for the next 10 years) seems to offer the best trade-off in achieving the desired improvements in performance. **Table 2** shows that results for the West area and western stock are hardly affected by these caps, and correspondingly for the east there are no meaningful differences compared to BR_6 for the R1 and R3 scenarios. BR_7 offers the highest lower 5%ile for AvC30 for the East area without unduly reducing the lower 5%ile for Br30 for the eastern stock. These consequences for the East area of TACs not dropping as low as under BR_6 are perhaps most clearly evident in **Figures 1b** and **3,** while **Figure 7** shows little by way of poorer projections for the eastern stock biomass for R2 scenarios when BR10 results are compared with those for BR_6.

A comparison of the results for BR10 with those for BR_6 in **Table 2a** shows the trade-off involved in limiting the maximum downward TAC change to 30% rather than 50%. The negative consequences are for the western stock, being greatest for the R2 scenarios. However, quantitatively at the lower 5%ile for Br30 for that stock, the reduction is only from 0.33 to 0.31, which would not seem a cause for particular conservation concern. Hence BR10 has been preferred for the BR Base CMP choice at this time.

The comparisons for different values of the development tuning target for the western stock (1.00, 1.25 and 1.50 – BR10, BR11 and BR12 respectively) in **Table 2b** and **Figure 1** show effectively no impact on performance for the East area or the eastern stock. For the west, however, there is the expected trade-off of lower catches for higher tuning targets. A similar comparison for tuning for the eastern stock (while maintaining median Br30 west = 1.00) is achieved by varying the value of the α control parameter (BR13 to BR16) in the formula for the East area TAC (equation A4a in **Appendix A**) – see **Table 2c** and **Figure 3**. The values considered correspond to tuning targets for median Br30 east from 1.17 to 2.47. Note that given the caps applied (to achieve better performance in other respects) in these CMPs for the East area catch (36000t to 2032 and 45 000t thereafter), it is not possible to bring the median Br30 east value much below 1.17. Again the expected trade-off, in this instance for the east, is evident: higher values of α lead to higher AvC30 values (though these are restricted to some extent by the caps on the East area TAC imposed by the BR CMPs), and lower values of Br30 east. However, there is also some impact on the west as well, with slightly lower catches and smaller values for lower 5%iles for Br30 west as the value of α is increased. To ascertain whether the catch performance for the East area could be improved, the cap on the post-2032 TACs in that area was increased from 45 kt for Br10 in steps of 5 kt for BR17 and then BR18, and eventually to 60 kt for BR19 – see **Table 2d** and **Figure 3.** This results in small increases in AvC30 for the East area, but at the expense of a substantial reduction in the lower 5%ile for Br30 east; for the west, median catches and also lower 5%iles for both catches and Br30 drop slightly as this cap for the East area TAC is increased.

Stochastic runs for BR10, BR11 and BR12, with results in Table 3 and plotted in **Figure 4,** show that when compared to deterministic results, median catches are hardly affected, but lower 5%iles are notably less especially for the West area. For both east and west, median Br30 values drop slightly, but lower 5%iles can drop appreciably, and the eastern stock can be extirpated for a few of the R2 OMs. **Figure 5** plots these stochastic results for BR10 for every OM, showing that the R2 problems occur especially for scenarios with a combination of low East area SSB scale (-- and +-) and low weight on the length composition data (L) (and hence higher east-west mixing); there are consequential problems for the western stock for some of these OMs (likely because less eastern origin fish in the West area leads to larger proportions of western origin fish in the catches there). **Figure 6** shows some of the associated stochastic trajectories to provide insight into why the eastern stock can on occasions become so heavily reduced in abundance; these plots indicate that the reason is that initially TACs for the East area are not decreased sufficiently far and fast. This negative aspect of the performance of BR10 possibly needs further investigation, leading perhaps to further refinement of this CMP.

The appreciable difference in performance for the East area and eastern stock for the R1 (and R3) compared to the R2 OM scenarios prompts inspection of projections of the abundance indices for the East area, which are shown stochastically for OM1 vs OM2 in **Figure 9** and deterministically across all the OM scenarios in the interim grid in **Figure 10.** What is immediately evident is that aside from the French aerial survey (which essentially reflects recently recruiting year classes), a substantial difference is clear, and occurs within the next five years. This in turn suggests that by the time of the first formal MP revision some five years hence, future data will have shown some of the current interim grid OMs to be inconsistent with the data, substantially reducing a key uncertainty. However, it needs to be kept in mind that R1 and R2 in a sense reflect "extreme" situations, with many situations intermediate between the two also plausible as the underlying reality, so that any actual distinction possible from future data is unlikely to be this clear-cut. Nevertheless, the considerable differences in performances between especially the R1 and R2 scenarios points strongly to the desirability of considering CMP performance results separately for each R scenario, rather than as some weighted average across the three.

Note that **Appendix A** provides mathematical specifications of the BR CMP. **Appendix B** illustrates the sensitivity of certain performance statistics to tuning the BR10 CMP to weighted rather than unweighted OMs.

Summary

The results from this paper suggest the following.

1) Modifying the BR CMP by placing additional caps on the East area TAC for the first 10 years, and reducing the maximum downward TAC change possible from 50% to 30%; this leads to CMP BR10.
2) Changing tuning targets for the western and eastern stock Br30 values leads to predictable trade-off with the catch in the respective West and East areas.
3) Stochastic results for BR10 show some instances of extirpation of the eastern stock for a few R2 OMs – this indicates a possible need for possible refinement of BR10, which may require a return to allowance for possibly larger TAC reductions for that area.
4) Presenting CMP results separately for each R scenario, rather than as some weighted average across the three.

Reference

Butterworth DS and Rademeyer RA. 2021. Further refinements of the BR CMP. Document presented at the January 2021 informal BFT CMP developers' meeting. ICCAT document SCRS/2021/018. 13 pp.

Table 1. Parameter values for each of the CMPs presented here. The tuning is for median Br30 west = 1.00 unless specifically indicated otherwise.

CMP name	α	β	γ	$s^{\text{threshold}}$	Note
BR_6	2.0	0.750	10	0	Final selection of January document
BR_7	2.0	0.770	10	0	as BR_6 but with 12-36 000t bound until 2032 in the East
BR_8	2.0	0.770	10	0	as BR_6 but with 10-36 000t bound until 2032 in the East
BR_9	2.0	0.765	10	0	as BR_6 but with 12-40 000t bound until 2032 in the East
BR10	2.0	0.770	10	0	as BR_7 but 30% max decrease instead of 50%
BR11	2.0	0.545	10	0	as BR10 but tuned to median western Br30=1.25
BR12	2.0	0.290	10	0	as BR10 but tuned to median western Br30=1.5
BR13	0.5	0.730	10	0	as BR10 but α=0.5
BR14	1.0	0.730	10	0	as BR10 but α=1
BR15	3.0	0.760	10	0	as BR10 but α=3
BR16	5.0	0.860	10	0	as BR10 but α=5
BR17	3.0	0.730	10	0	as BR16 but 50 000t cap instead of 45 000t
BR18	3.0	0.710	10	0	as BR16 but 55 000t cap instead of 45 000t
BR19	3.0	0.710	10	0	as BR16 but 60 000t cap instead of 45 000t

Table 2a. Deterministic Br30 and AvC30 values (median of the RS) for CMPs BR_6 to BR10 first for all OMs in the interim grid ("All scenarios"), and then for each recruitment scenarios separately (R1 then R2 then R3). AvC30 values are in '000 mt.

	All scenarios		R1 scenarios only		R2 scenarios only		R3 scenarios only	
	Br30	AvC30	Br30	AvC30	Br30	AvC30	Br30	AvC30
EAST								
Zero catch	3.41 (2.10; 4.13)	0.00 (0.00; 0.00)	3.66 (3.32; 4.19)	0.00 (0.00; 0.00)	2.33 (1.98; 2.66)	0.00 (0.00; 0.00)	3.48 (2.83; 4.09)	0.00 (0.00; 0.00)
BR_6 Final selection of Jan doc	1.50 (0.80; 2.69)	38.34 (12.44; 44.28)	2.23 (1.81; 2.79)	44.28 (44.28; 44.28)	1.37 (1.04; 1.64)	16.99 (11.08; 20.77)	1.46 (0.71; 2.04)	38.34 (35.53; 42.39)
BR_7 12-36 000t bound to 2032	1.55 (0.86; 2.78)	36.40 (14.97; 41.28)	2.32 (1.92; 2.86)	41.28 (41.28; 41.28)	1.25 (0.92; 1.64)	18.02 (13.61; 20.57)	1.53 (0.80; 2.11)	36.40 (33.51; 40.37)
BR_8 10-36 000t bound to 2032	1.55 (0.87; 2.78)	36.40 (14.90; 41.28)	2.32 (1.92; 2.86)	41.28 (41.28; 41.28)	1.28 (0.94; 1.64)	17.95 (13.75; 20.55)	1.53 (0.80; 2.11)	36.40 (33.51; 40.37)
BR_9 12-40 000t bound to 2032	1.51 (0.82; 2.73)	37.47 (14.34; 43.00)	2.27 (1.86; 2.82)	43.00 (43.00; 43.00)	1.28 (0.92; 1.64)	18.15 (12.80; 20.81)	1.49 (0.74; 2.07)	37.47 (34.67; 41.59)
BR10 30% max down (BC)	1.55 (0.85; 2.78)	36.44 (14.45; 41.28)	2.32 (1.92; 2.86)	41.28 (41.28; 41.28)	1.24 (0.88; 1.64)	18.18 (13.76; 20.82)	1.52 (0.78; 2.11)	36.44 (33.51; 40.37)
WEST								
Zero catch	2.78 (1.49; 3.31)	0.00 (0.00; 0.00)	3.15 (2.89; 3.45)	0.00 (0.00; 0.00)	1.82 (1.17; 2.23)	0.00 (0.00; 0.00)	2.78 (2.45; 3.12)	0.00 (0.00; 0.00)
BR_6 Final selection of Jan doc	1.00 (0.36; 1.91)	2.05 (1.49; 3.16)	1.54 (0.65; 2.03)	2.50 (1.99; 3.58)	0.70 (0.35; 1.29)	1.95 (1.46; 2.68)	1.04 (0.32; 1.42)	2.14 (1.71; 2.69)
BR_7 12-36 000t bound to 2032	1.00 (0.35; 1.90)	2.11 (1.53; 3.26)	1.56 (0.66; 2.04)	2.58 (2.04; 3.65)	0.67 (0.34; 1.26)	1.82 (1.45; 2.08)	1.04 (0.32; 1.43)	2.21 (1.77; 2.74)
BR_8 10-36 000t bound to 2032	1.00 (0.35; 1.90)	2.11 (1.53; 3.26)	1.56 (0.66; 2.04)	2.58 (2.04; 3.65)	0.68 (0.34; 1.26)	1.82 (1.46; 2.09)	1.04 (0.32; 1.43)	2.21 (1.77; 2.74)
BR_9 12-40 000t bound to 2032	1.00 (0.36; 1.90)	2.08 (1.49; 3.20)	1.55 (0.65; 2.03)	2.54 (2.02; 3.61)	0.68 (0.35; 1.26)	1.79 (1.40; 2.06)	1.04 (0.32; 1.42)	2.17 (1.74; 2.70)
BR10 30% max down (BC)	1.00 (0.35; 1.90)	2.11 (1.50; 3.26)	1.56 (0.66; 2.04)	2.58 (2.04; 3.65)	0.67 (0.34; 1.26)	1.80 (1.41; 2.07)	1.04 (0.31; 1.43)	2.21 (1.77; 2.74)

Table 2b. Deterministic Br30 and AvC30 values (median of the RS) for CMPs BR10 to BR12 (the three tunings) first for all OMs in the interim grid ("All scenarios"), and then for each recruitment scenarios separately (R1 then R2 then R3). AvC30 values are in '000 mt.

	All scenarios		R1 scenarios only		R2 scenarios only		R3 scenarios only	
	Br30	AvC30	Br30	AvC30	Br30	AvC30	Br30	AvC30
EAST								
Zero catch	3.41 (2.10; 4.13)	0.00 (0.00; 0.00)	3.66 (3.32; 4.19)	0.00 (0.00; 0.00)	2.33 (1.98; 2.66)	0.00 (0.00; 0.00)	3.48 (2.83; 4.09)	0.00 (0.00; 0.00)
BR10 tuned to West median 1.00	1.55 (0.85; 2.78)	36.44 (14.45; 41.28)	2.32 (1.92; 2.86)	41.28 (41.28; 41.28)	1.24 (0.88; 1.64)	18.18 (13.76; 20.82)	1.52 (0.78; 2.11)	36.44 (33.51; 40.37)
BR11 tuned to West median 1.25	1.56 (0.86; 2.79)	36.53 (14.49; 41.28)	2.33 (1.93; 2.87)	41.28 (41.28; 41.28)	1.25 (0.90; 1.64)	18.33 (13.78; 20.90)	1.53 (0.79; 2.12)	36.53 (33.60; 40.41)
BR12 tuned to West median 1.5	1.57 (0.87; 2.80)	36.64 (14.51; 41.28)	2.34 (1.95; 2.88)	41.28 (41.28; 41.28)	1.27 (0.92; 1.64)	18.46 (13.78; 20.97)	1.54 (0.81; 2.13)	36.64 (33.68; 40.46)
WEST								
Zero catch	2.78 (1.49; 3.31)	0.00 (0.00; 0.00)	3.15 (2.89; 3.45)	0.00 (0.00; 0.00)	1.82 (1.17; 2.23)	0.00 (0.00; 0.00)	2.78 (2.45; 3.12)	0.00 (0.00; 0.00)
BR10 tuned to West median 1.00	1.00 (0.35; 1.90)	2.11 (1.50; 3.26)	1.56 (0.66; 2.04)	2.58 (2.04; 3.65)	0.67 (0.34; 1.26)	1.80 (1.41; 2.07)	1.04 (0.31; 1.43)	2.21 (1.77; 2.74)
BR11 tuned to West median 1.25	1.25 (0.48; 2.16)	1.63 (1.21; 2.51)	1.85 (0.96; 2.31)	1.96 (1.50; 2.85)	0.88 (0.45; 1.46)	1.40 (1.14; 1.64)	1.26 (0.48; 1.72)	1.71 (1.34; 2.32)
BR12 tuned to West median 1.5	1.50 (0.72; 2.54)	1.04 (0.84; 1.55)	2.15 (1.46; 2.67)	1.19 (0.96; 1.74)	1.14 (0.59; 1.68)	0.94 (0.81; 1.09)	1.47 (0.74; 2.09)	1.11 (0.88; 1.54)

Table 2c. Deterministic Br30 and AvC30 values (median of the RS) for CMPs BR10 and BR13 to BR16 (decreasing Br30 east) first for all OMs in the interim grid ("All scenarios"), and then for each recruitment scenarios separately (R1 then R2 then R3). AvC30 values are in '000 mt.

	All scenarios		R1 scenarios only		R2 scenarios only		R3 scenarios only	
	Br30	AvC30	Br30	AvC30	Br30	AvC30	Br30	AvC30
EAST								
BR13 lower Eastern Br30 (α=0.5)	2.47 (1.38; 3.49)	17.42 (10.13; 24.46)	2.98 (2.41; 3.55)	20.76 (19.32; 27.08)	1.63 (1.23; 2.17)	10.53 (9.79; 11.32)	2.52 (1.71; 3.20)	17.42 (15.77; 21.58)
BR14 lower Eastern Br30 (α=1)	1.97 (1.16; 2.99)	29.15 (12.23; 40.50)	2.46 (1.92; 3.10)	36.21 (33.63; 40.95)	1.47 (1.10; 1.97)	13.50 (11.79; 14.89)	1.98 (1.12; 2.62)	29.15 (26.35; 34.78)
BR10 30% max down (α=2)	1.55 (0.85; 2.78)	36.44 (14.45; 41.28)	2.32 (1.92; 2.86)	41.28 (41.28; 41.28)	1.24 (0.88; 1.64)	18.18 (13.76; 20.82)	1.52 (0.78; 2.11)	36.44 (33.51; 40.37)
BR15 higher Eastern Br30 (α=3)	1.38 (0.75; 2.78)	38.85 (16.47; 41.28)	2.32 (1.92; 2.86)	41.28 (41.28; 41.28)	1.09 (0.78; 1.40)	20.97 (14.85; 24.63)	1.32 (0.67; 1.92)	38.85 (36.35; 41.19)
BR16 higher Eastern Br30 (α=5)	1.17 (0.59; 2.78)	40.59 (19.56; 41.28)	2.32 (1.92; 2.86)	41.28 (41.28; 41.28)	0.82 (0.57; 1.12)	24.33 (16.88; 29.05)	1.17 (0.61; 1.84)	40.59 (39.12; 41.28)
WEST								
BR13 lower Eastern Br30 (a=0.5)	1.00 (0.39; 1.99)	2.60 (1.70; 3.83)	1.59 (0.68; 2.07)	3.04 (2.35; 4.13)	0.60 (0.30; 1.27)	2.03 (1.65; 2.30)	1.16 (0.43; 1.61)	2.82 (2.23; 3.11)
BR14 lower Eastern Br30 (a=1)	1.00 (0.41; 1.90)	2.27 (1.60; 3.36)	1.59 (0.68; 2.03)	2.68 (2.11; 3.76)	0.66 (0.33; 1.30)	1.89 (1.54; 2.16)	1.15 (0.44; 1.49)	2.36 (1.91; 2.84)
BR10 30% max down (a=2)	1.00 (0.35; 1.90)	2.11 (1.50; 3.26)	1.56 (0.66; 2.04)	2.58 (2.04; 3.65)	0.67 (0.34; 1.26)	1.80 (1.41; 2.07)	1.04 (0.31; 1.43)	2.21 (1.77; 2.74)
BR15 higher Eastern Br30 (a=3)	1.00 (0.34; 1.92)	2.08 (1.48; 3.22)	1.57 (0.67; 2.05)	2.55 (2.02; 3.61)	0.68 (0.35; 1.23)	1.77 (1.39; 2.04)	0.99 (0.26; 1.41)	2.18 (1.75; 2.72)
BR16 higher Eastern Br30 (a=5)	1.00 (0.31; 1.93)	2.06 (1.45; 3.18)	1.58 (0.68; 2.06)	2.53 (1.99; 3.58)	0.67 (0.34; 1.19)	1.73 (1.35; 1.99)	0.98 (0.23; 1.41)	2.16 (1.73; 2.70)

Table 2d. Deterministic Br30 and AvC30 values (median of the RS) for CMPs BR10 and BR17 to BR19 (increasing the post 2032 TAC cap for the East area) first for all OMs in the interim grid ("All scenarios"), and then for each recruitment scenarios separately (R1 then R2 then R3). AvC30 values are in '000 mt.

	All scenarios		R1 scenarios only		R2 scenarios only		R3 scenarios only	
	Br30	AvC30	Br30	AvC30	Br30	AvC30	Br30	AvC30
EAST								
BR10 cap 45 000t	1.55 (0.85; 2.78)	36.44 (14.45; 41.28)	2.32 (1.92; 2.86)	41.28 (41.28; 41.28)	1.24 (0.88; 1.64)	18.18 (13.76; 20.82)	1.52 (0.78; 2.11)	36.44 (33.51; 40.37)
BR17 as BR16, cap 50 000t	1.30 (0.68; 2.68)	40.26 (16.50; 43.95)	2.23 (1.80; 2.76)	43.95 (43.95; 43.95)	1.09 (0.78; 1.40)	21.00 (14.90; 24.64)	1.24 (0.55; 1.83)	40.26 (37.40; 43.52)
BR18 as BR16, cap 55 000t	1.24 (0.59; 2.59)	41.38 (16.53; 46.40)	2.15 (1.70; 2.66)	46.40 (46.40; 46.40)	1.09 (0.78; 1.40)	21.02 (14.94; 24.66)	1.15 (0.49; 1.76)	41.38 (38.40; 45.26)
BR19 as BR16, cap 60 000t	1.19 (0.51; 2.51)	42.47 (16.53; 48.74)	2.07 (1.60; 2.57)	48.74 (48.74; 48.74)	1.09 (0.78; 1.40)	21.02 (14.94; 24.66)	1.05 (0.44; 1.71)	42.47 (38.98; 47.06)
WEST								
BR10 cap 45 000t	1.00 (0.35; 1.90)	2.11 (1.50; 3.26)	1.56 (0.66; 2.04)	2.58 (2.04; 3.65)	0.67 (0.34; 1.26)	1.80 (1.41; 2.07)	1.04 (0.31; 1.43)	2.21 (1.77; 2.74)
BR17 as BR16, cap 50 000t	1.00 (0.34; 1.93)	1.99 (1.45; 3.08)	1.58 (0.69; 2.07)	2.44 (1.93; 3.50)	0.70 (0.36; 1.26)	1.72 (1.36; 1.98)	0.99 (0.25; 1.42)	2.09 (1.65; 2.65)
BR18 as BR16, cap 55 000t	1.00 (0.30; 1.92)	1.94 (1.42; 2.98)	1.58 (0.70; 2.08)	2.36 (1.87; 3.41)	0.72 (0.37; 1.27)	1.69 (1.34; 1.95)	0.99 (0.24; 1.43)	2.03 (1.57; 2.60)
BR19 as BR16, cap 60 000t	0.99 (0.26; 1.90)	1.93 (1.42; 2.94)	1.55 (0.69; 2.06)	2.34 (1.86; 3.40)	0.72 (0.37; 1.27)	1.69 (1.34; 1.95)	0.97 (0.21; 1.42)	2.02 (1.54; 2.59)

Table 3. Deterministic vs stochastic Br30 and AvC30 values (median of the RS) for CMPs BR10 to BR12 (the three median Br30 west tunings) first for all OMs in the interim grid (“All scenarios”), and then for each recruitment scenarios separately (R1 then R2 then R3). AvC30 values are in ‘000 mt.

	All scenarios		R1 scenarios only		R2 scenarios only		R3 scenarios only	
	Br30	AvC30	Br30	AvC30	Br30	AvC30	Br30	AvC30
EAST								
BR10 deterministic	1.55 (0.85; 2.78)	36.44 (14.45; 41.28)	2.32 (1.92; 2.86)	41.28 (41.28; 41.28)	1.24 (0.88; 1.64)	18.18 (13.76; 20.82)	1.52 (0.78; 2.11)	36.44 (33.51; 40.37)
BR11 deterministic	1.56 (0.86; 2.79)	36.53 (14.49; 41.28)	2.33 (1.93; 2.87)	41.28 (41.28; 41.28)	1.25 (0.90; 1.64)	18.33 (13.78; 20.90)	1.53 (0.79; 2.12)	36.53 (33.60; 40.41)
BR12 deterministic	1.57 (0.87; 2.80)	36.64 (14.51; 41.28)	2.34 (1.95; 2.88)	41.28 (41.28; 41.28)	1.27 (0.92; 1.64)	18.46 (13.78; 20.97)	1.54 (0.81; 2.13)	36.64 (33.68; 40.46)
BR10 stochastic	1.47 (0.45; 2.75)	36.99 (11.28; 41.28)	2.30 (1.58; 3.02)	41.28 (40.26; 41.28)	1.00 (0.00; 1.92)	13.23 (9.75; 19.14)	1.32 (0.60; 2.04)	37.06 (31.15; 40.78)
BR11 stochastic	1.49 (0.47; 2.76)	36.94 (11.31; 41.28)	2.31 (1.59; 3.04)	41.28 (40.33; 41.28)	1.01 (0.00; 1.94)	13.24 (9.90; 19.58)	1.34 (0.62; 2.08)	36.96 (31.15; 40.41)
BR12 stochastic	1.51 (0.45; 2.77)	36.95 (11.31; 41.28)	2.33 (1.61; 3.05)	41.28 (40.05; 41.28)	1.02 (0.00; 1.92)	13.33 (9.95; 19.95)	1.37 (0.66; 2.07)	37.02 (31.12; 40.44)
WEST								
BR10 deterministic	1.00 (0.35; 1.90)	2.11 (1.50; 3.26)	1.56 (0.66; 2.04)	2.58 (2.04; 3.65)	0.67 (0.34; 1.26)	1.80 (1.41; 2.07)	1.04 (0.31; 1.43)	2.21 (1.77; 2.74)
BR11 deterministic	1.25 (0.48; 2.16)	1.63 (1.21; 2.51)	1.85 (0.96; 2.31)	1.96 (1.50; 2.85)	0.88 (0.45; 1.46)	1.40 (1.14; 1.64)	1.26 (0.48; 1.72)	1.71 (1.34; 2.32)
BR12 deterministic	1.50 (0.72; 2.54)	1.04 (0.84; 1.55)	2.15 (1.46; 2.67)	1.19 (0.96; 1.74)	1.14 (0.59; 1.68)	0.94 (0.81; 1.09)	1.47 (0.74; 2.09)	1.11 (0.88; 1.54)
BR10 stochastic	0.93 (0.14; 1.97)	2.05 (0.88; 3.14)	1.47 (0.66; 2.20)	2.49 (1.74; 3.42)	0.66 (0.10; 1.38)	1.30 (0.65; 1.87)	0.76 (0.09; 1.42)	2.27 (1.62; 2.98)
BR11 stochastic	1.13 (0.26; 2.19)	1.59 (0.75; 2.49)	1.74 (0.95; 2.43)	1.91 (1.34; 2.69)	0.80 (0.16; 1.50)	1.08 (0.59; 1.58)	1.01 (0.25; 1.63)	1.74 (1.25; 2.42)
BR12 stochastic	1.42 (0.43; 2.50)	1.01 (0.61; 1.57)	2.05 (1.35; 2.81)	1.16 (0.89; 1.70)	1.02 (0.24; 1.71)	0.78 (0.53; 1.00)	1.28 (0.50; 2.01)	1.11 (0.85; 1.53)

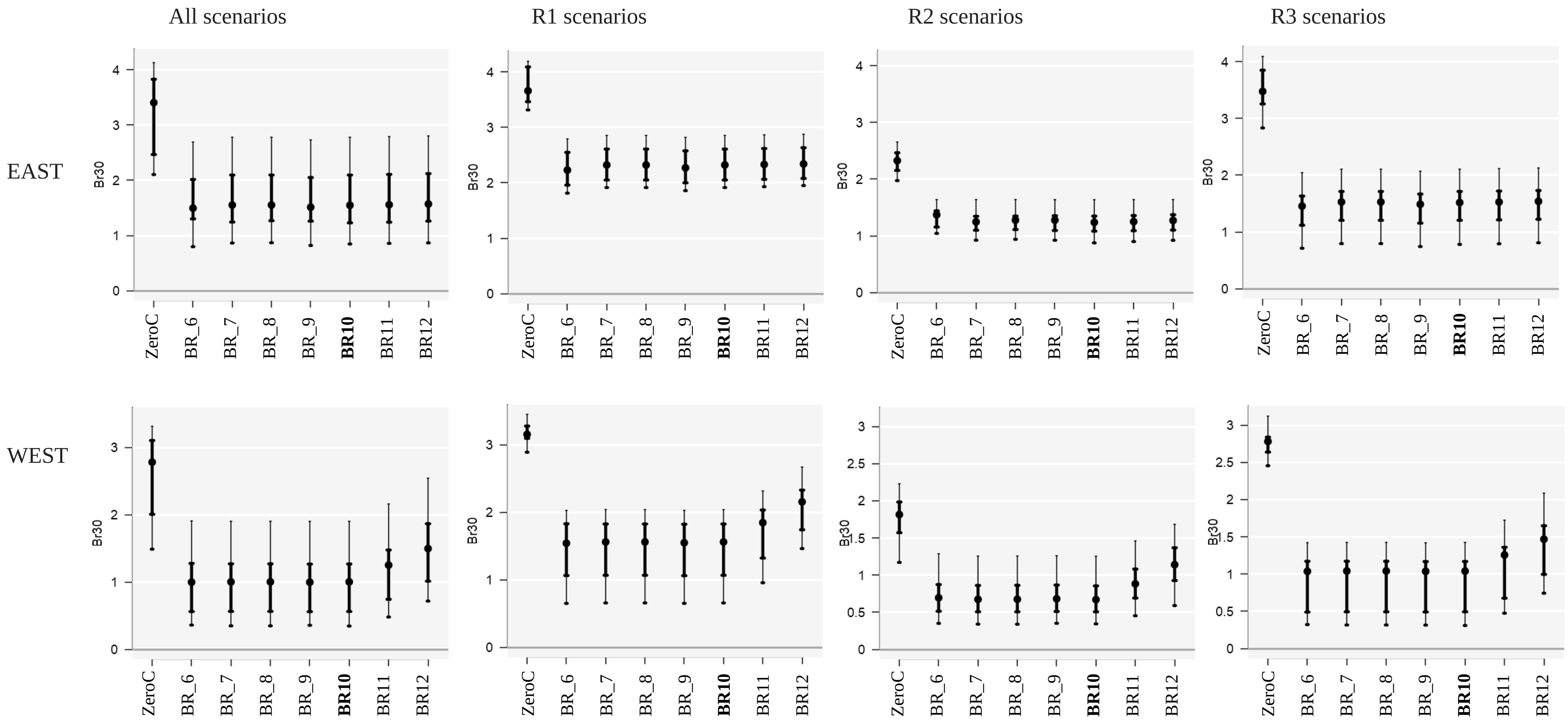


Figure 1a. Deterministic Br30 values for zero catch and the CMPs considered over the interim grid of OMs for CMPs BR_6 to BR12) first for all OMs in the interim grid ("All scenarios"), and then for each of the recruitment scenarios separately, showing median, interquartile and 90%-ile ranges. These CMP variants primarily first vary bounds on the East area TAC for the first ten years (BR_6 to BR_9), and then modify the median Br30- west tuning target (BR10 to BR12).

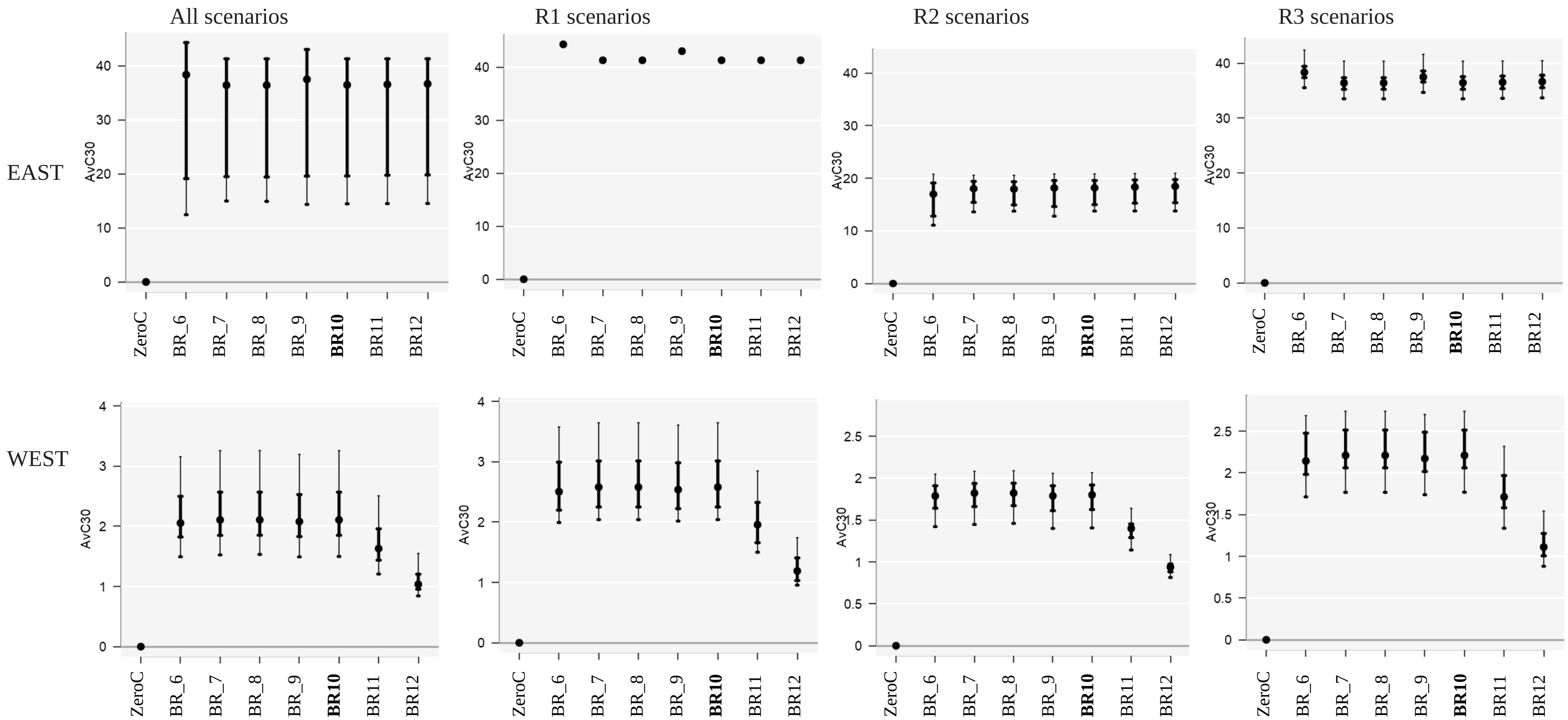


Figure 1b. Deterministic AvC30 values for zero catch and the CMPs considered over the interim grid of OMs for CMPs BR_6 to BR12) first for all OMs in the interim grid ("All scenarios"), and then for each of the recruitment scenarios separately, showing median, interquartile and 90%-ile ranges. These CMP variants primarily first vary bounds on the East area TAC for the first ten years (BR_6 to BR_9), and then modify the median Br30- west tuning target (BR10 to BR12).

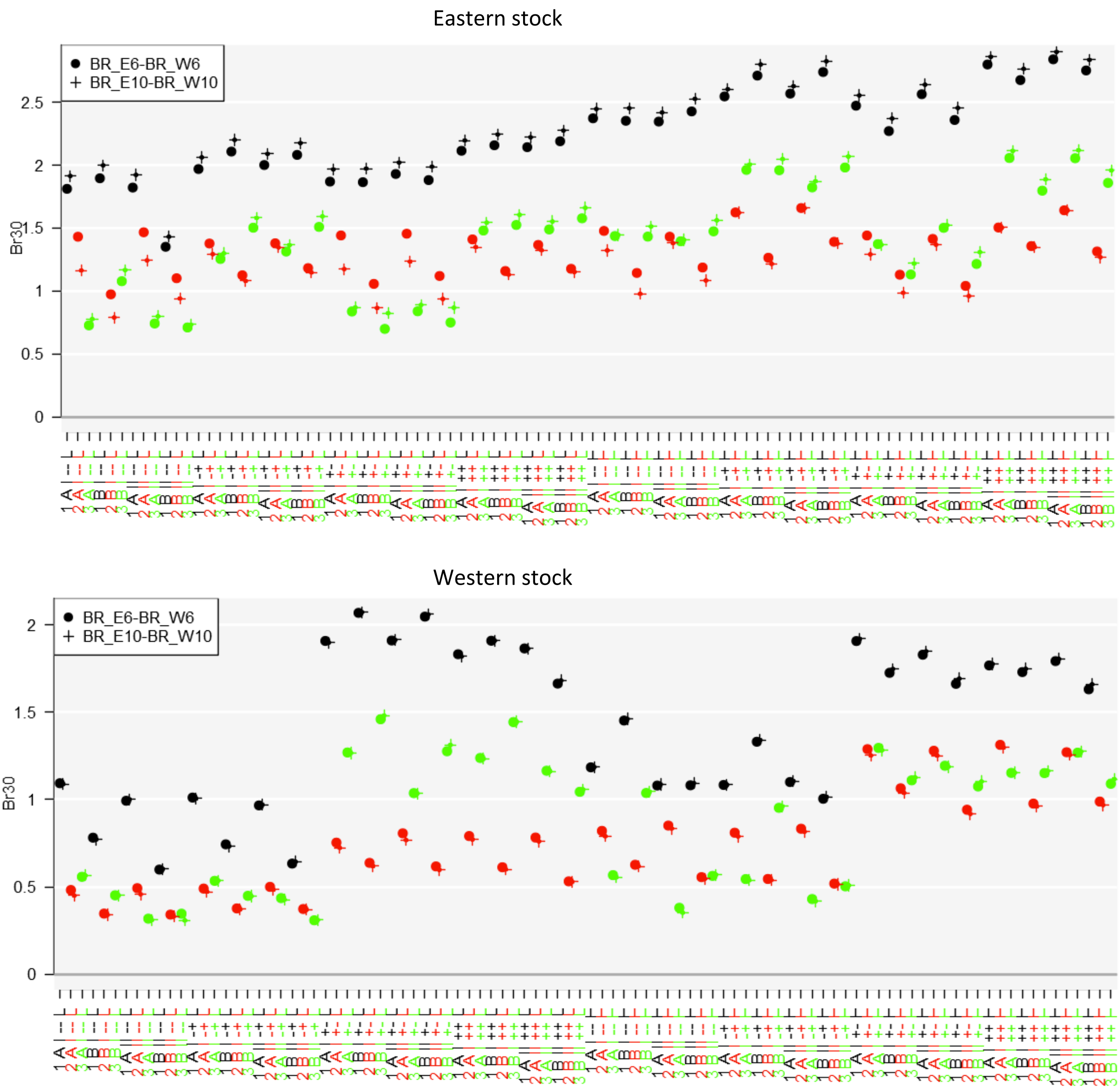


Figure 2a.Deterministic Br30 results for BR_6 and BR10. The three colours correspond to the three recruitment scenarios: black, red and green to R1, R2 and R3 respectively.

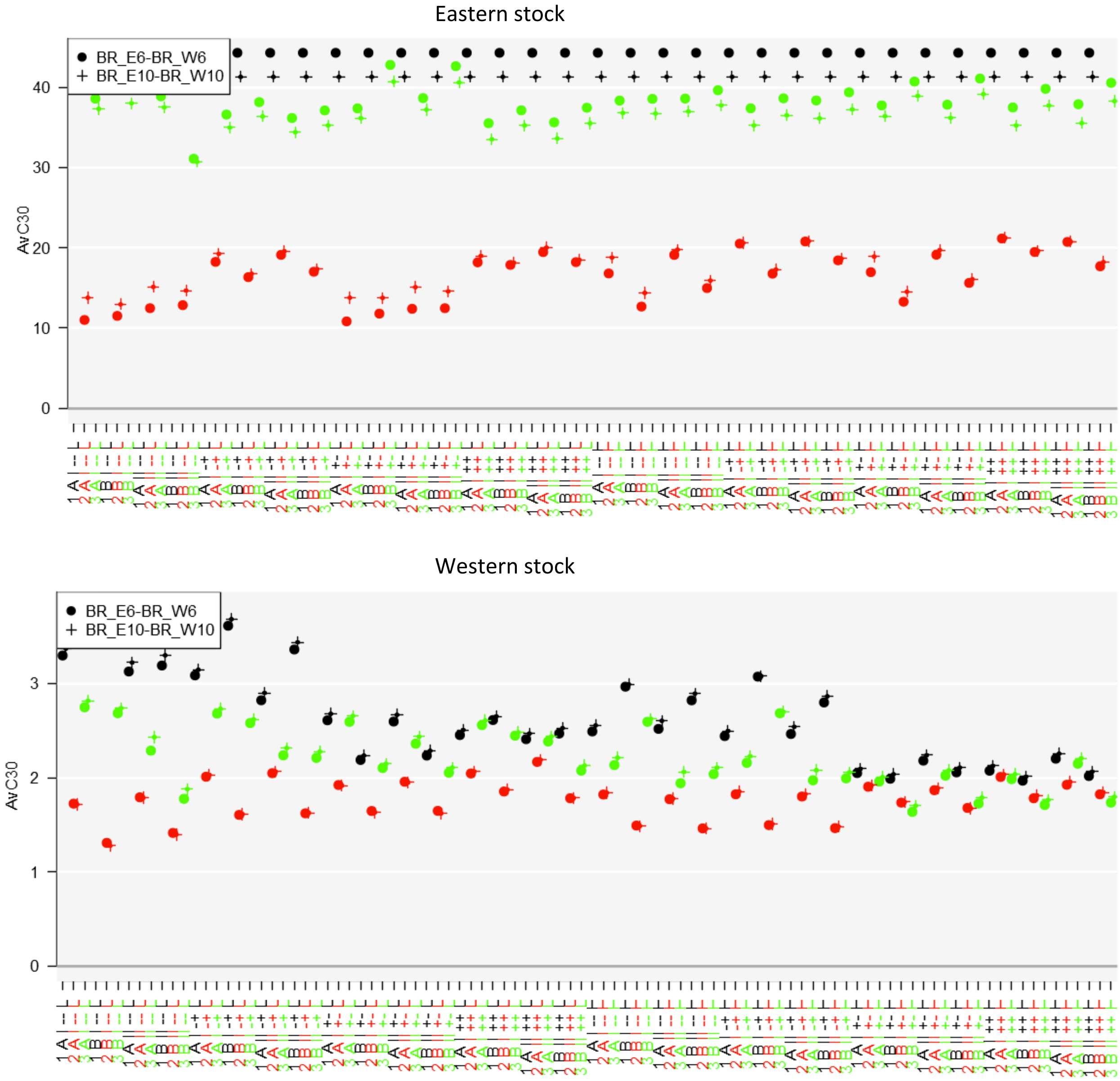


Figure 2b. Deterministic AvC30 results for BR_6 and BR10. The three colours correspond to the three recruitment scenarios: black, red and green to R1, R2 and R3 respectively.

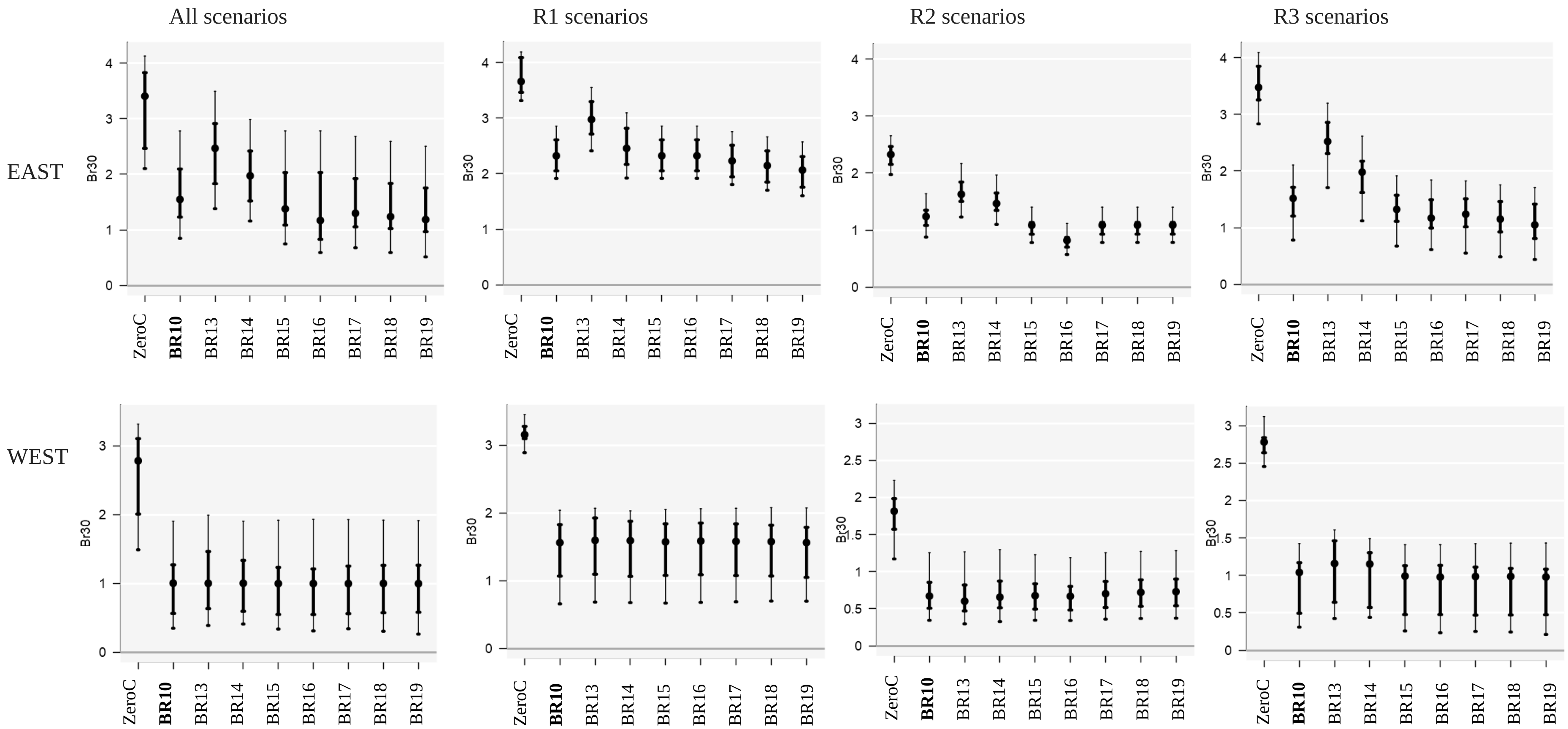


Figure 3a. Deterministic Br30 values for zero catch and the CMPs considered over the interim grid of OMs for CMPs BR10 and BR13 to BR19 first for all OMs in the interim grid ("All scenarios"), and then for each of the recruitment scenarios separately, showing median, interquartile and 90%-ile ranges. These CMP variants first vary the value of the α control parameter for the East area TAC calculation (BR13 to BR16), and then vary the post-2032 cap on the East area TAC (BR17 to BR19).

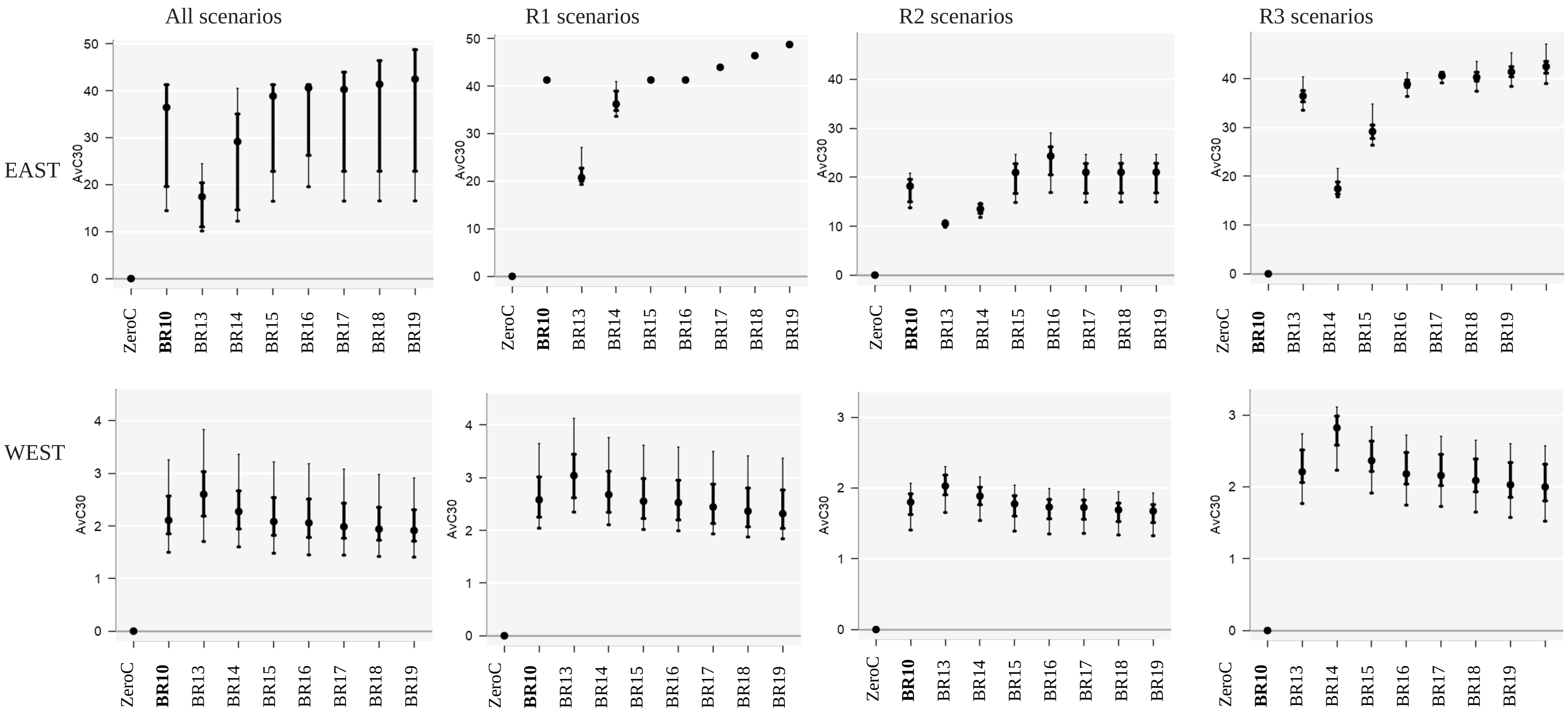


Figure 3b. Deterministic AvC30 values for zero catch and the CMPs considered over the interim grid of OMs for CMPs BR10 and BR13 to BR19) first for all OMs in the interim grid ("All scenarios"), and then for each of the recruitment scenarios separately, showing median, interquartile and 90%-ile ranges. These CMP variants first vary the value of the α control parameter for the East area TAC calculation (BR13 to BR16), and then vary the post-2032 cap on the East area TAC (BR17 to BR19).

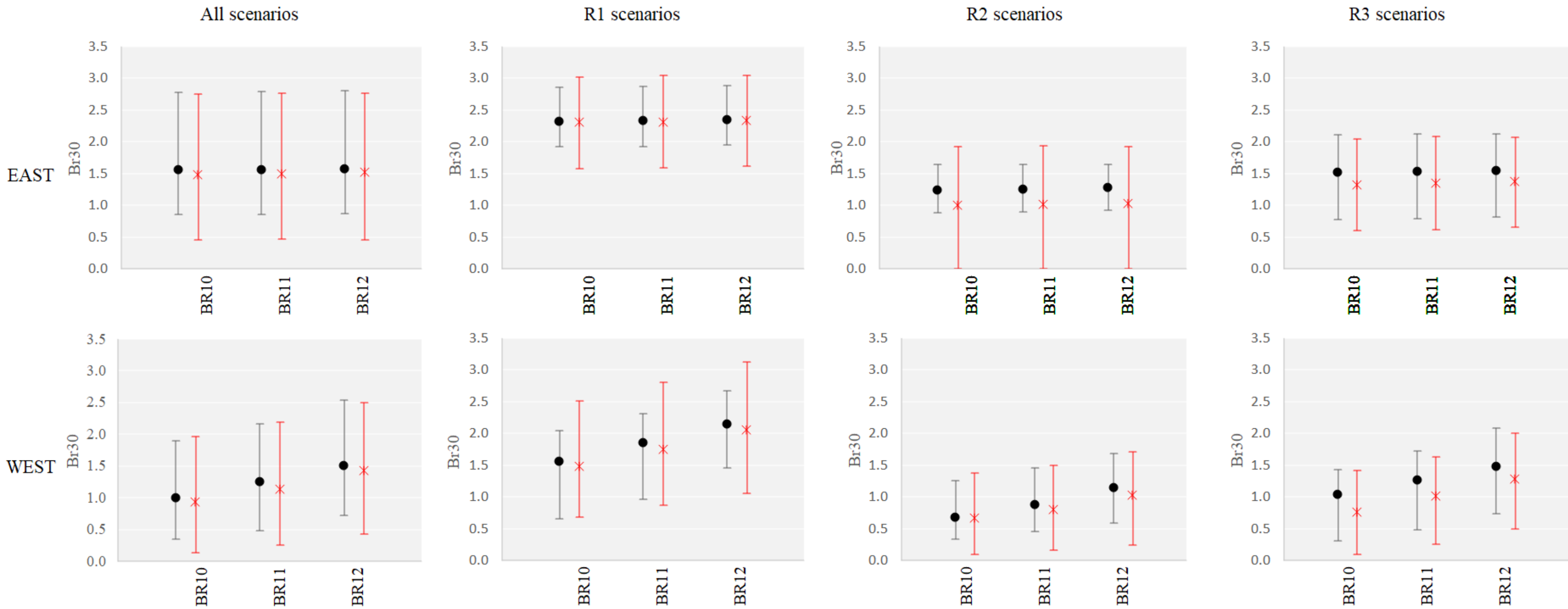


Figure 4a. Deterministic (black dots) and stochastic (red crosses) Br30 values for zero catch and the CMPs considered over the interim grid of OMs for CMPs BR10 to BR12 first for all OMs in the interim grid ("All scenarios"), and then for each of the recruitment scenarios separately, showing median, interquartile and 90%-ile ranges.

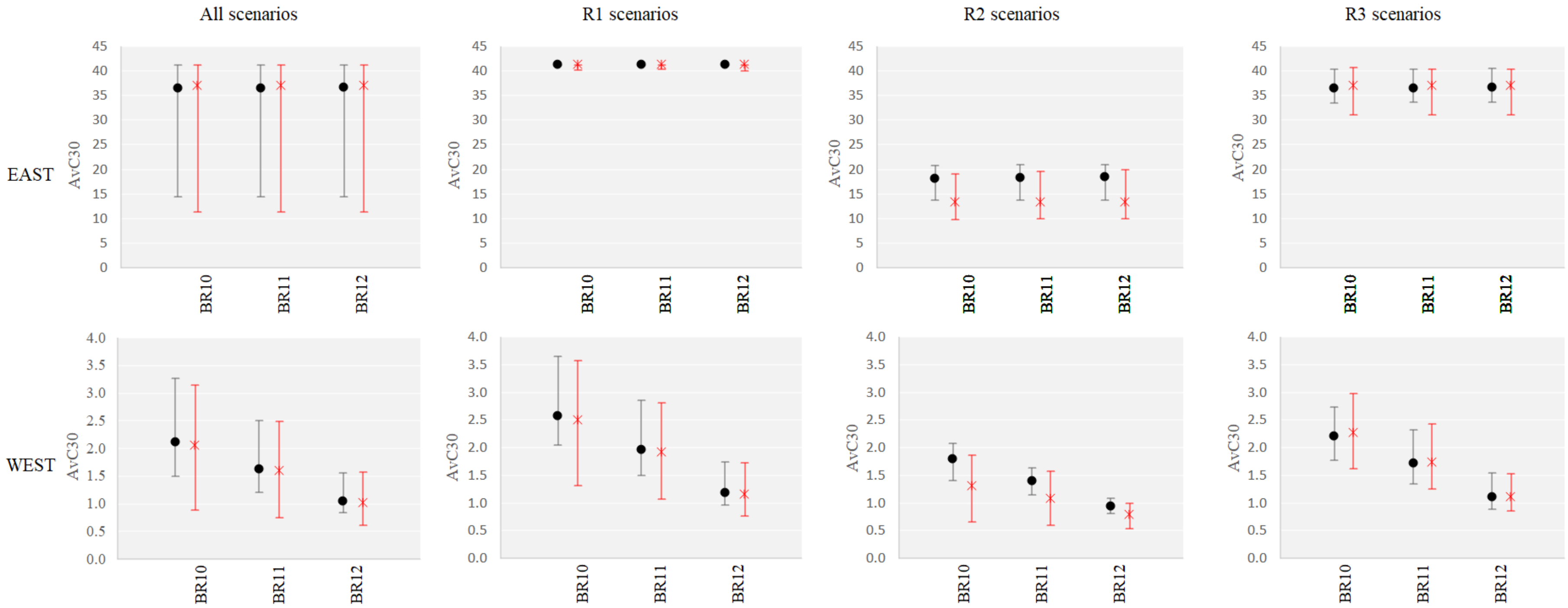
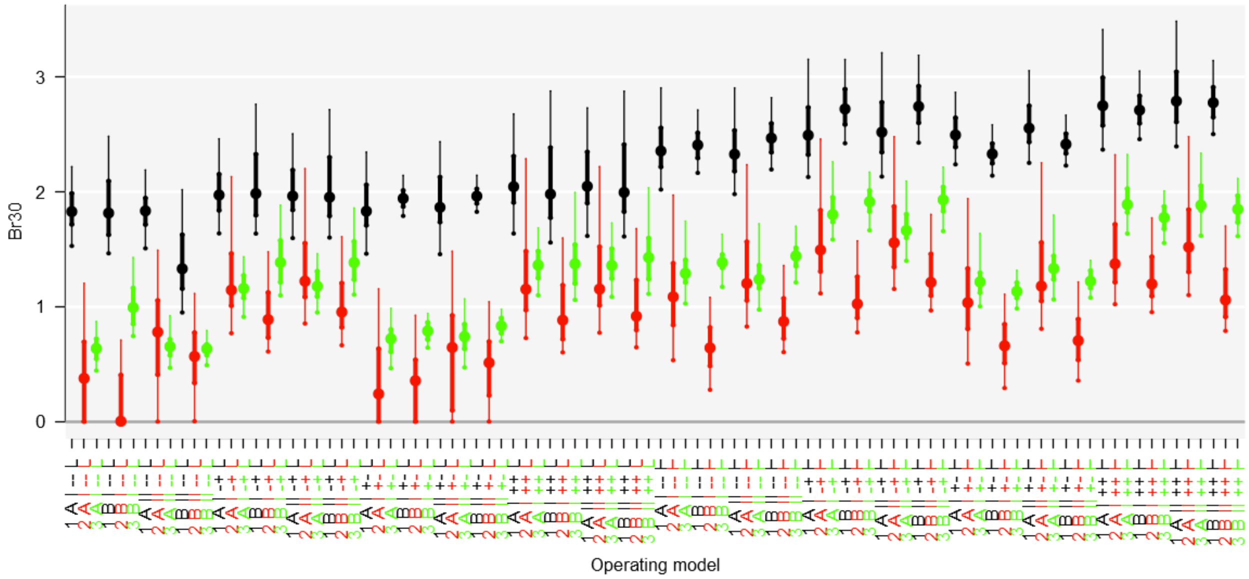


Figure 4b. Deterministic (black dots) and stochastic (red crosses) AvC30 values for zero catch and the CMPs considered over the interim grid of OMs for CMPs BR10 to BR12 first for all OMs in the interim grid ("All scenarios"), and then for each of the recruitment scenarios separately, showing median, interquartile and 90%-ile ranges.



Western stock

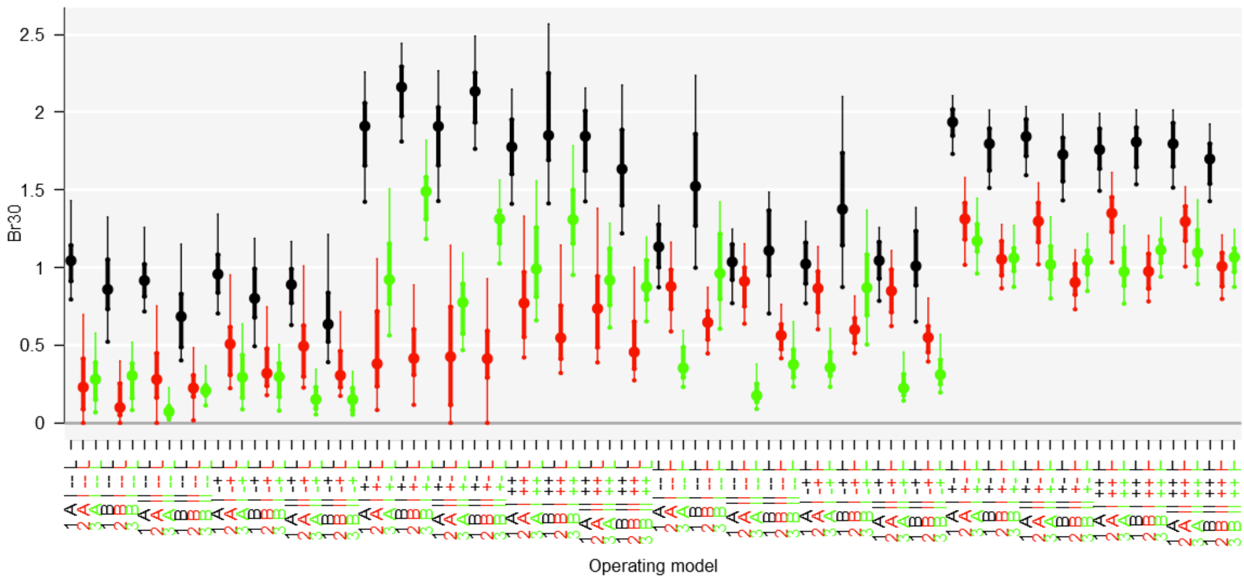


Figure 5a. Stochastic Br30 results for BR10. The three colours correspond to the three recruitment scenarios: black, red and green to R1, R2 and R3 respectively.

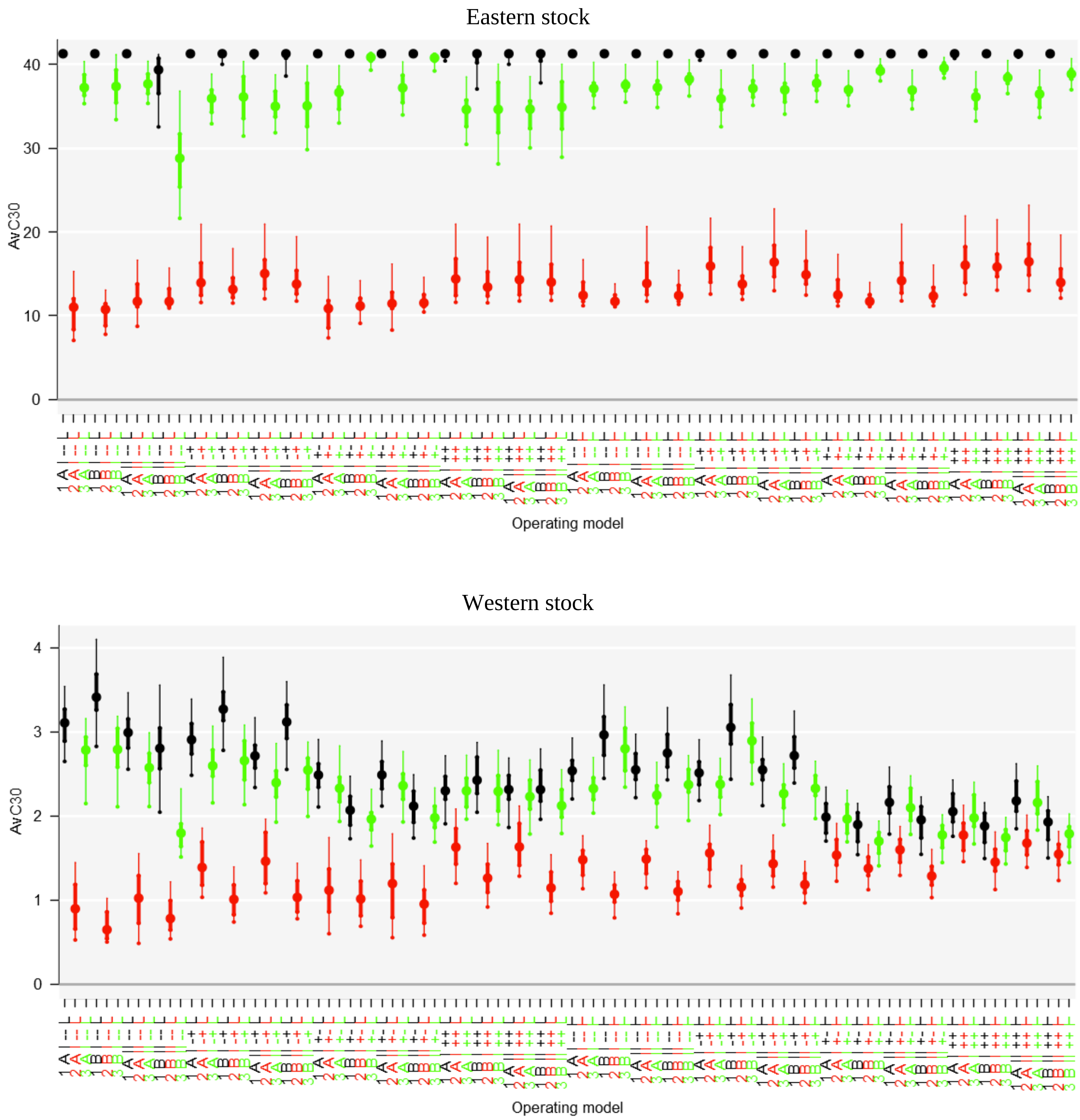


Figure 5b. Stochastic AvC30 results for BR10. The three colours correspond to the three recruitment scenarios: black, red and green to R1, R2 and R3 respectively.

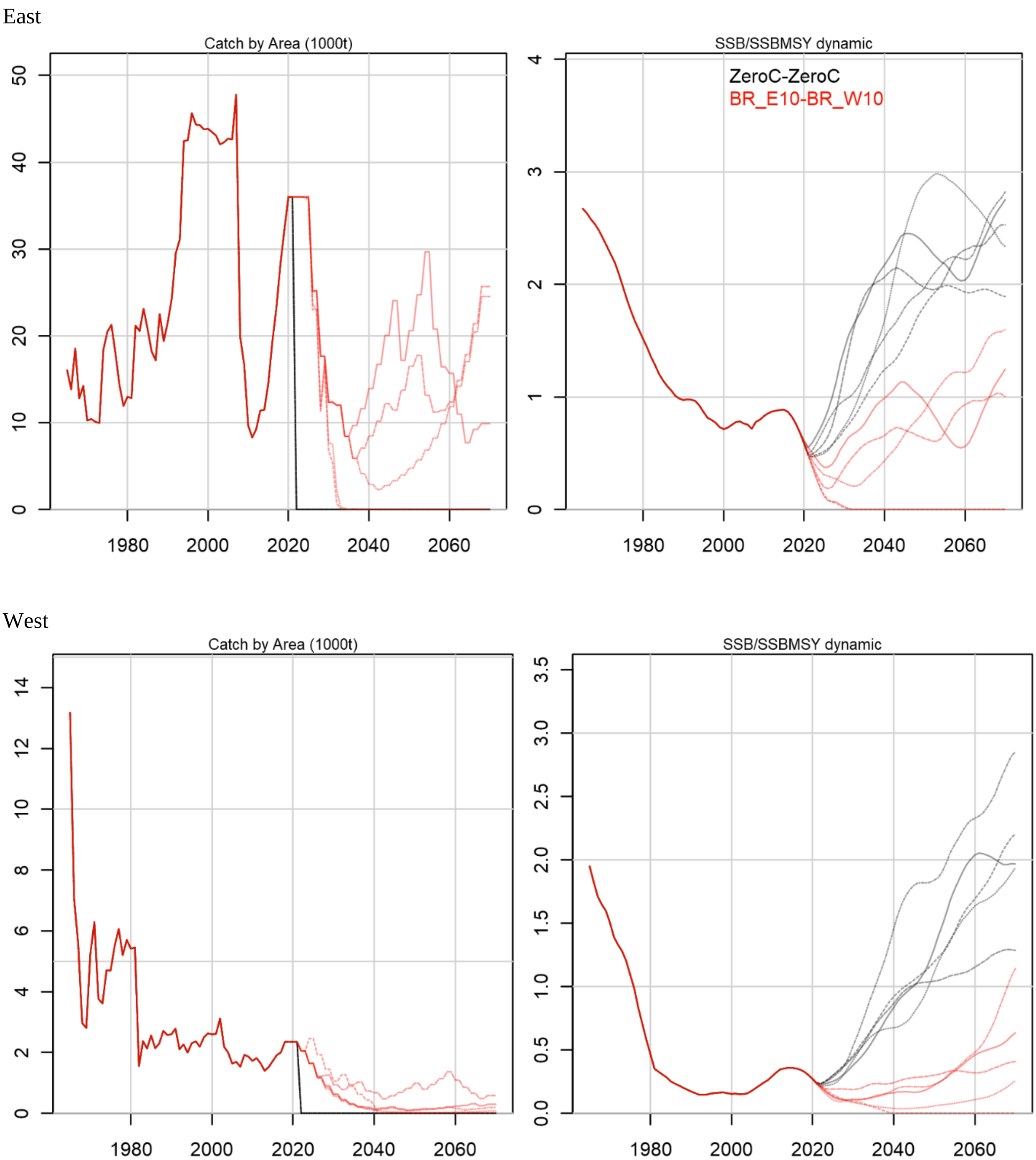


Figure 6. Five simulated catch and biomass trajectories for the stochastic runs for OM2 (R2, A, I, --, L) under zero catch (black lines) and BR10 (red lines).

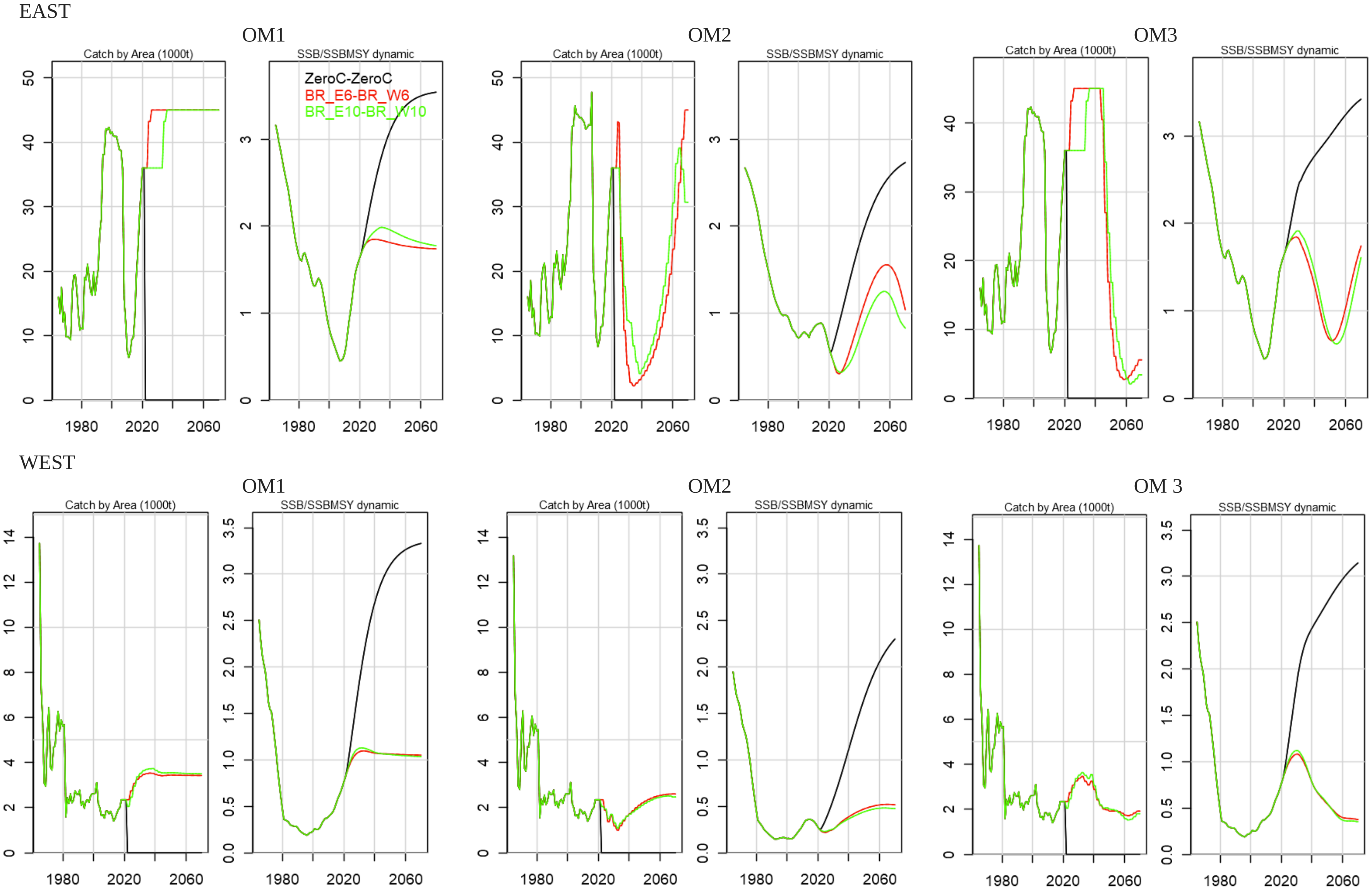


Figure 7. Deterministic catch and SSB/SSBMSY projections under zero catch, BR_6 and BR10, for OM1, OM2 and OM3.

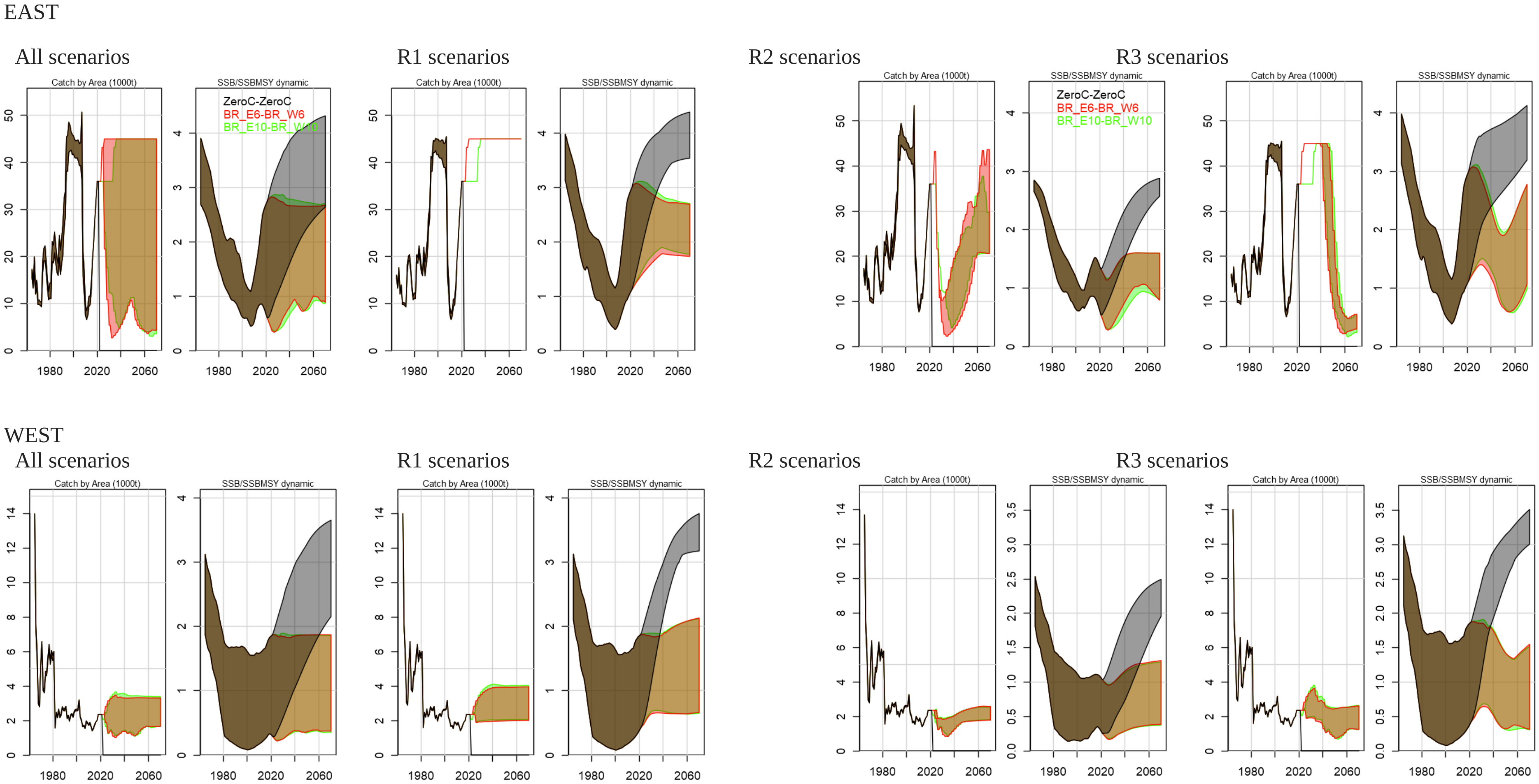


Figure 8. Upper and lower 5%ile catch and SSB/SSBMSY deterministic projections over the interim grid of OMs under zero catch, BR_6 and BR10, for each of the three recruitment scenarios separately.

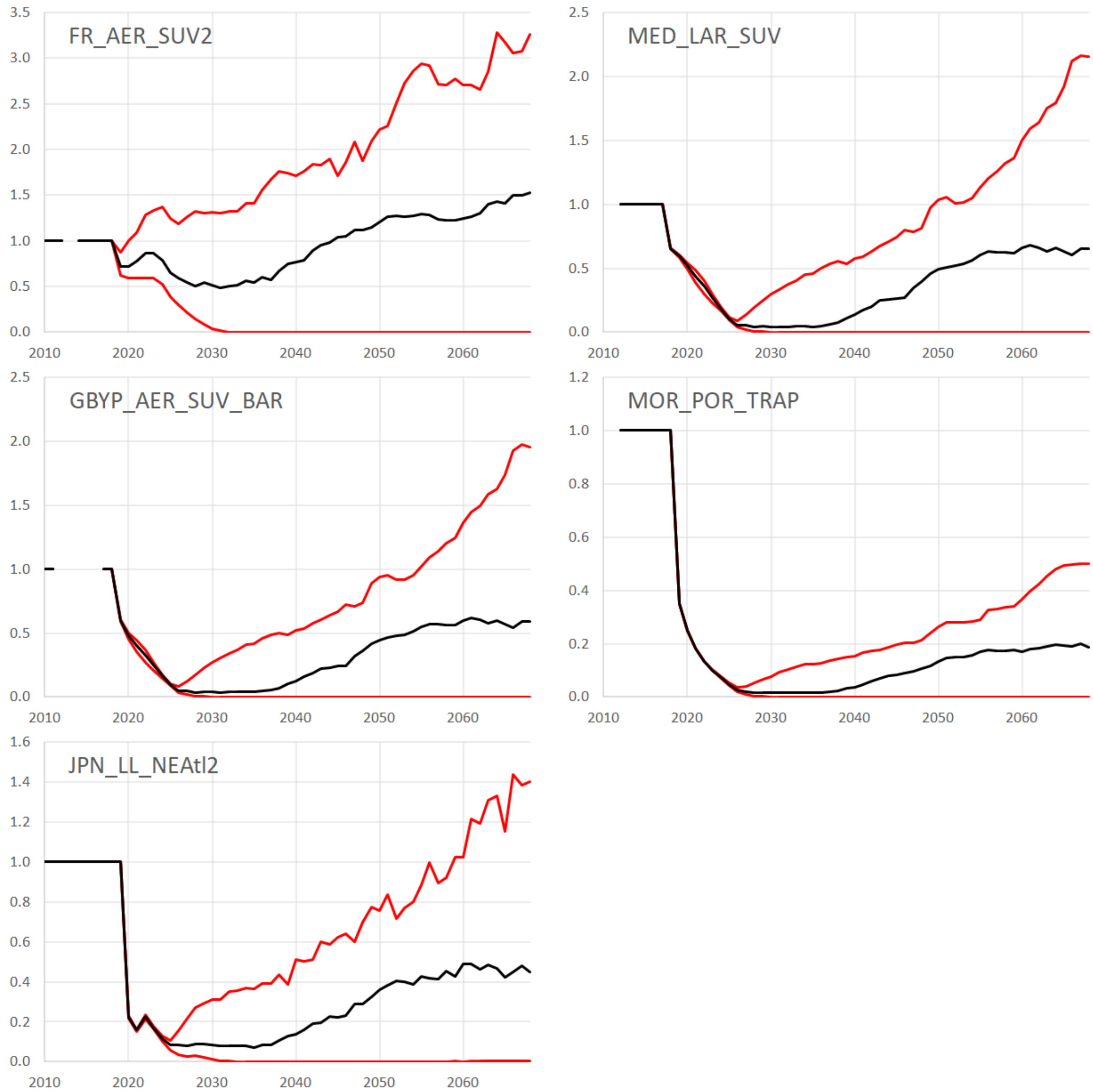


Figure 9. Medians (black lines) and 90%iles (red lines) OM2 vs OM1 ratios of each abundance index, projected stochastically under BR_7.

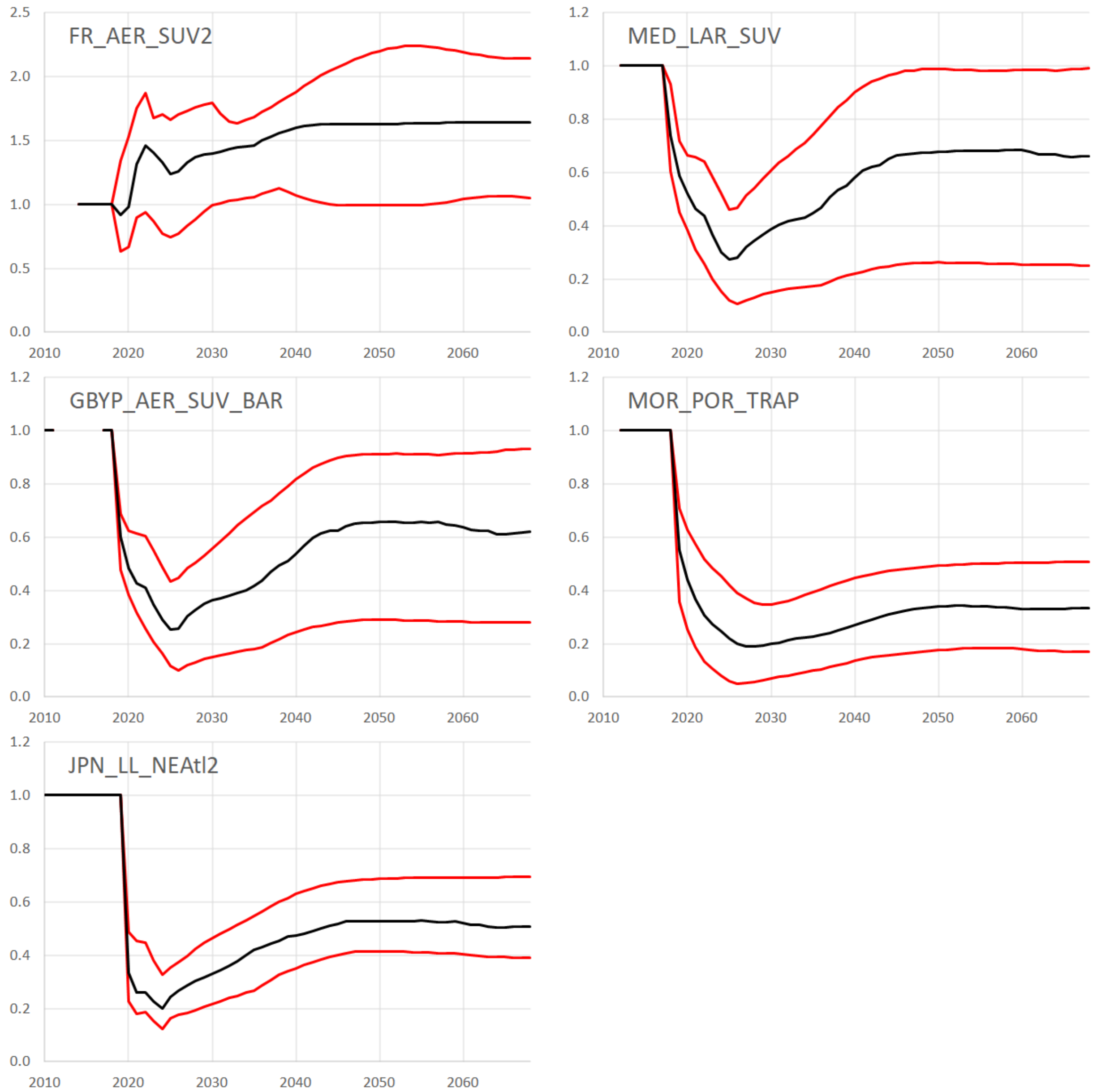


Figure 10. Medians (black lines) and 90%iles (red lines) R2 vs R1 ratios of each abundance index, projected deterministically under BR_7. Here the statistics shown are for the distribution of these ratios across linked OM scenarios in the interim grid.

Appendix A

The CMP is empirical, based on inputs related to abundance indices which are first standardised for magnitude, then aggregated by way of a weighted average of all indices available for the East and the West areas, and finally smoothed over years to reduce observation error variability effects. TACs are then set based on the concept of taking a fixed proportion of the abundance present, as indicated by these aggregated and smoothed abundance indices. The details are set out below.

Aggregate abundance indices

An aggregate abundance index is developed for each of the East and the West areas by first standardising each index available for that area to an average value of 1 over the past years for which the index appeared reasonably stable[2], and then taking a weighted average of the results for each index, where the weight is inversely proportional to the variance of the residuals used to generate future values of that index in the future modified to take into account the loss of information content as a result of autocorrelation. The mathematical details are as follows.

J_y is an average index over *n* series (*n*=5 for the East area and *n*=7 for the West area)[3]:

$$J_y = \frac{\sum_i^n w_i \times I_y^{i*}}{\sum_i^n w_i} \tag{A1}$$

Where

$$w_i = \frac{1}{(\sigma^i)^2}$$

and where the standardised index for each index series (*i*) is:

$$I_y^{i*} = I_y^i \Big/ Average\ of\ historical\ I_y^i \tag{A2}$$

σ^i is computed as

$$\sigma^i = \frac{SD^i}{1-AC^i}$$

where SD^i is the standard deviation of the residuals in log space and AC^i is their autocorrelation, averaged over the OMs, as used for generating future pseudo-data. Table 1 lists these values for σ^i.

2017 is used for the "average of historical I_y^i". For the East, the 2017 Mediterranean larval survey index value was not previously available, but is now and has been included in the computation.

The actual index used in the CMPs, $J_{av,y}$, is the average over the last three years for which data would be available at the time the MP would be applied, hence:

$$J_{av,y} = \frac{1}{3}\left(J_y + J_{y-1} + J_{y-2}\right) \tag{A3}$$

where the *J* applies either to the East or to the West area.

[2] These years are for the Eastern indices: 2014-2017 for FR_AER_SUV2, 2012-2016 for MED_LAR_SUV, 2015-2018 for GBYP_AER_SUV_BAR, 2012-2018 for MOR_POR_TRAP and 2012-2019 for JPN_LL_NEAtl2; and for the Western indices: 2006-2017 for GOM_LAR_SURV, 2006-2018 for all US_RR and US_GOM_PLL2 indices, 2010-2019 for JPN_LL_West2 and 2006-2017 for CAN_SWNS.

[3] For the aerial surveys, there is no value for 2013, 2018 and 2019 (French) and 2017-2019 (Mediterranean). For GBYP aerial survey there is no value for 2012, 2014, 2016 and 2019. For MOR_POR_TRAP survey, there is no value for 2019. These years were omitted from this averaging where relevant.

CMP specifications

The BR Fixed Proportion CMPs tested set the TAC every second year simply as a multiple of the J_{av} value for the area at the time (see Figure 1), but subject to the change in the TAC for each area being restricted to a maximum of 20% (up or down). The formulae are given below.

For the East area:

$$TAC_{E,y} = \begin{cases} \left(\frac{TAC_{E,2020}}{J_{E,2017}}\right) \cdot \alpha \cdot J^E_{av,y-2} & \text{for } J^E_{av,y} \geq T^E \\ \left(\frac{TAC_{E,2020}}{J_{E,2017}}\right) \cdot \alpha \cdot \frac{\left(J^E_{av,y-2}\right)^2}{T^E} & \text{for } J^E_{av,y} < T^E \end{cases}$$

(A4a)

For the West area:

$$TAC_{W,y} = \begin{cases} \left(\frac{TAC_{W,2020}}{J_{W,2017}}\right) \cdot \beta \cdot J^W_{av,y-2} & \text{for } J^W_{av,y} \geq T^W \\ \left(\frac{TAC_{W,2020}}{J_{W,2017}}\right) \cdot \beta \cdot \frac{\left(J^W_{av,y-2}\right)^2}{T^E} & \text{for } J^W_{av,y} < T^W \end{cases}$$

(A4b)

Note that in equation (A4a), setting $\alpha = 1$ will amount to keeping the TAC the same as for 2020 until the abundance indices change. If α or $\beta > 1$ harvesting will be more intensive than at present, and for α or $\beta < 1$ it will be less intensive.

Below *T*, the law is parabolic rather than linear at low abundance (i.e. below some threshold, so as to reduce the proportion taken by the fishery as abundance drops); this is to better enable resource recovery in the event of unintended depletion of the stock. For the results presented here, the choices $T^E = 1$ and $T^W = 1$ have been made.

Constraints on the extent of TAC increase and decrease

Maximum increase:

If $TAC_{i,y} \geq 1.2 * TAC_{i,y-1}$ then $TAC_{i,y} = 1.2 * TAC_{i,y-1}$ (A5)

with the subscript *i* corresponding to either East or West area.

Maximum decrease:

If $TAC_{i,y} \leq 0.8 * TAC_{i,y-1}$

then $TAC_{i,y} = (1 - maxdecr) * TAC_{i,y-1}$ (A6)

where

$$maxdecr = \begin{cases} 0.2 & J^i_{av,y-2} \geq J_{i,2017} \\ \text{linear btw 0.2 and } D & J_{i,2017} < J^i_{av,y-2} < J_{i,2017} \\ D & J^i_{av,y-2} \leq 0.5 J_{i,2017} \end{cases} \quad \text{(A7)}$$

where *D*=0.5 or 0.3 in implementations to date.

Maximum TAC

A cap on the maximum allowable TAC is set. This can potentially improve performance, particularly in the event of a shift to a lower productivity regime. By ensuring that TACs have not risen so high that they cannot be reduced sufficiently rapidly following such an event to adjust for the lower resource productivity. In investigations to date, this has been found to be useful to implement only for the East area, where TACs can otherwise rise to in excess of 70 kt.

New trend-based term in the West

The TAC in the West is further adjusted if a measure of immediate past trend in the indices is below a threshold value:

If $s_y^W \leq s^{threshold}$

$$TAC_{W,y} \rightarrow \left[1 + \gamma\left(s_y^W - s^{threshold}\right)\right]TAC_{W,y} \qquad \text{(A8)}$$

where

s_y^W is a measure of the immediate past trend in the average index J_y (equation 1), and

γ and $s^{threshold}$ are control parameter values.

This trend measure is computed by linearly regressing lnJ_y *vs* year *y*' for y'=y-6 to y'=y-2 to yield the regression slope s_y^W.

Table A1. σ^i values used in weighting when averaging over the indices to provide composite indices for the East and the West areas (see equation A1).

EAST		WEST	
Index name	σ^i	Index name	σ^i
MOR_POR_TRAP	0.56	GOM_LAR_SUV	0.58
JPN_LL_NEAtl2	0.45	JPN_LL_West2	0.62
FR_AER_SUV2	1.00	US_RR_66_114	1.47
GBYP_AER_SUV_B.	0.56	US_RR_115_144	0.71
MED_LAR_SUV	0.56	US_RR_177	1.29
		US_GOM_PLL2	0.89
		CAN SWNS	1.71

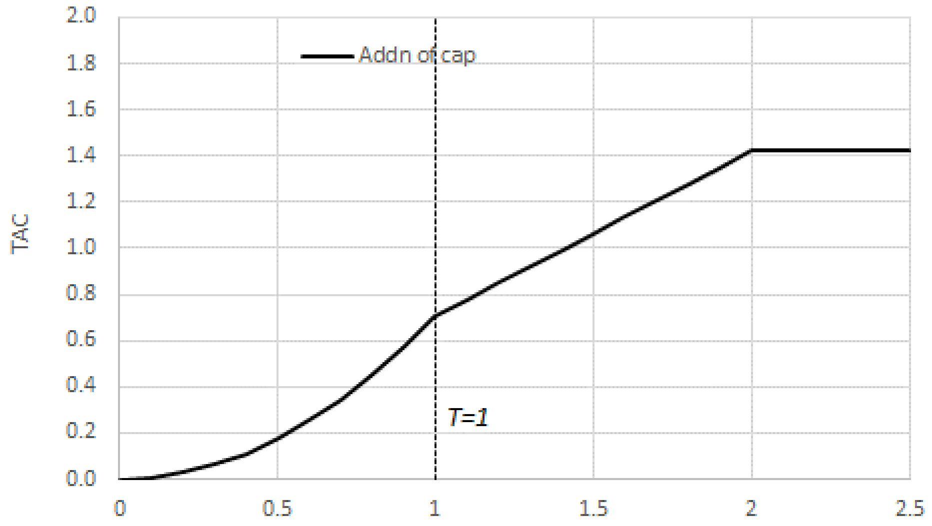


Figure A1. Illustrative relationship (the "catch control law") of *TAC* against $J_{av,y}$ for the BR CMP, which includes the parabolic decrease below T and the capping of the TAC so as not to exceed some maximum value.

Appendix B

A simple illustration of the effects of the weighting of OMs suggested by the poll on CMP performance

The results from the plausibility weighting poll (Kimoto and Walter, 2021) for the different levels on the uncertainty axes in the interim grid of Operating Models (OMs) are considered here in the context of a simple illustration of their effect on key performance statistics for one of the CMPs (the current preferred Butterworth-Rademeyer CMP variant BR10).

To keep the illustration simple, the equal weights of the levels on two of those uncertainty axes have been left unchanged, as the poll results scarcely differed from such equality. Furthermore, the equal weights for the recruitment axis have also been maintained, as ultimately the three recruitment scenarios may be handled in a different manner. Focus then is restricted to modifying the equal weights for the four pairs of levels on the abundance scale axis to the non-trivially different ones suggested by the poll, *viz.* from 25% weight each to 28.9, 30.5, 17.0 and 23.6% for the --, -+, +- and ++ scale options respectively.

In the Table below, the first row shows the original equal OM weighting results for BR10, and the next how they change when the abundance scale level weightings are used instead. In the final row, BR20 is the same as BR10, but retuned for the scale level weighting scenario to again give a median Br30 = 1.00 for the western origin stock.

The main message from these initial and illustrative results is that including the poll weighting outcomes does not lead to much change in the values of the major overall performance statistics (for averages over the interim grid OMs).

Reference

Kimoto A. and Walter JF. 2021. Summary of the Atlantic Bluefin tuna MSE pol for plausibility weighting. ICCAT document SCRS/2021/029. 11 pp.

Table B1. Deterministic median and 90%iles Br30 and AvC30 for BR10 with equal weighting of the OMs, and for BR10 and BR20 with unequal weighting of the OMs where BR20 is the equivalent of BR10 but tuned to the median Br30 west of 1 with unequal weighting.

	Br30		AvC30	
	EAST	WEST	EAST	WEST
BR10 equal weighting	1.55 (0.85; 2.78)	1.00 (0.35; 1.90)	36.44 (14.45; 41.28)	2.11 (1.50; 3.26)
BR10 unequal weighting	1.56 (0.81; 2.78)	0.94 (0.33; 1.86)	36.38 (14.38; 41.28)	2.13 (1.48; 3.30)
BR20 unequal weighting (tuned)	1.56 (0.80; 2.78)	1.00 (0.35; 1.89)	36.41 (14.39; 41.28)	2.03 (1.44; 3.17)