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REFINEMENTS OF THE BR CMP AS OF JULY 2021

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SUMMARY

The BR CMPs first advanced by Butterworth and Rademeyer (2021) are first refined, and then their tuning parameters are adjusted to meet the development tuning options specified at the April 2021 meeting of the Bluefin Tuna Species Working Group for the reconditioned OMs. Discussion focuses on the results from the stochastic runs of these CMPs, as ultimately any MP eventually adopted will need to show satisfactory performance for such scenarios, which better reflect reality for future data. The lower tuning targets yield results that would likely be considered unacceptable because of a fair number of OMs for which especially low percentiles of Br30 distributions are rather small. Hence, future CMP options considered should probably be restricted to tuning targets for the eastern and western stock median (over the grid OMs) Br30 values which do not extend much below 1.5 and 1.25 respectively. The resource conservation performance for some of the robustness tests is open to question, more so for the western stock.

RÉSUMÉ

Les CMP BR initialement proposées par Butterworth et Rademeyer (2021) ont d'abord été affinées, puis leurs paramètres de calibrage ont été ajustés pour répondre aux options de calibrage du développement spécifiées lors de la réunion d'avril 2021 du Groupe d'espèces sur le thon rouge pour les OM reconditionnées. La discussion se concentre sur les résultats des scénarios stochastiques de ces CMP, car en fin de compte, toute MP finalement adoptée devra montrer des performances satisfaisantes pour de tels scénarios, qui reflètent mieux la réalité pour les données futures. Les résultats de la production des objectifs de calibrage inférieurs seraient probablement considérés comme inacceptables en raison d'un bon nombre d'OM pour lesquels les centiles particulièrement bas des distributions de Br30 sont plutôt petits. Par conséquent, les futures options de CMP envisagées devraient probablement se limiter à des objectifs de calibrage pour les valeurs Br30 de la médiane du stock oriental et occidental (de la matrice d'OM) qui ne s'étendent pas beaucoup en dessous de 1,5 et 1,25 respectivement. La performance en matière de conservation des ressources pour certains des tests de robustesse est sujette à caution, surtout pour le stock occidental.

RESUMEN

Los CMP BR avanzados por Butterworth y Rademeyer (2021) han sido primero refinados y, posteriormente, se han ajustado sus parámetros de calibración para cumplir las opciones de la calibración del desarrollo especificadas en la reunión de abril de 2021 del Grupo de especies de atún rojo para los OM recondicionados. La discusión se centra en los resultados de los ensayos estocásticos de estos CMP, ya que en última instancia cualquier MP adoptado eventualmente tendrá que mostrar un desempeño satisfactorio para dichos escenarios, que reflejan mejor la realidad para los datos futuros. Los resultados del rendimiento de los objetivos de calibración inferiores probablemente serían considerados inaceptables a causa de un buen número de OM para los que los especialmente bajos percentiles de las distribuciones de Br30 son muy pequeños. Por tanto, las opciones futuras de CMP consideradas debería ser restringidas probablemente a objetivos de calibración para los valores Br30 de la mediana del stock occidental y oriental (de la matriz de OM) que no se extienden muy por debajo de 1,5 y 1,25, respectivamente. El desempeño en cuanto a conservación del recurso para algunas de las pruebas de robustez está abierto a preguntas, más aun para el stock occidental.

KEYWORDS

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

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Introduction

This paper refines the BR CMPs first advanced by Butterworth and Rademeyer (2021), and then adjusts their tuning parameters to meet the development tuning options (for median Br30 values for the eastern and western stocks for deterministic runs of the revised grid OMs – see **Table 1**) as specified at the April 2021 meeting of the Bluefin Tuna Species Working Group (ICCAT, 2021) for the reconditioned OMs. Results are shown for both deterministic and stochastic runs. One of these CMPs is applied to the robustness test OMs.

Appendix A provides mathematical specifications for the BR CMP.

The package ABTMSE v7.1.3 was used to generate the results reported.

Results

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

The deterministic Br30 and AvC30 results for all CMPs are given in **Table 2**, with a visual representation in **Figure 1.** The equivalent stochastic results are given in **Table 3 and Figure 2.**

The stochastic Br30 and AvC30 values under the BR1 (1.00 East – 1.00 West tuning) and BR2 (1.25 East – 1.25 West tuning) CMPs for each of the 96 OMs of the interim grid are compared in **Figure 3,** and similarly under BR3 (1.50 East – 1.25 West tuning) and BR4 (1.50 East – 1.50 West tuning) in **Figure 4,** and under BR3 (no caps in the West) and BR3* (caps in the West) in **Figure 5**. The Br30 vs AvC30 trade-off plots are given in Figure 6 for each of the CMPs. **Figure 7** summarises the problems in terms of achieving adequate resource conservation for some OMs in terms of the results for Br30 for each of the CMPs; note that the option of capping the West area TAC at its current value of 2350 t until 2030 was introduced for BR2 and BR3 (to give BR2* and BR3* - see **Table 1**) in an attempt to restore adequacy in resource conservation performance.

Stochastic robustness tests' results under BR3 are given in **Table 4** and plotted in **Figure 8.**

Noe that omitting the US_RR_177 index in the CMP computations does not affect the tuning (unsurprisingly as this index has such a low relative weight – see Table A1 in Appendix A.

Discussion

This discussion focuses primarily on the results from the stochastic runs of the tuned CMPs, as ultimately any MP eventually adopted will need to show satisfactory performance for these scenarios, which better reflect reality as regards future data.

The trade-offs plots in **Figure 6** provide perhaps the first important insight into performance of these BR CMPs. The lower tunings (such as BR1) are questionable in resource conservation terms, given the lower 5%iles for their Br30 values approaching zero; however, the arguably "safe" option in those terms of the higher tuning of BR4 sees lower catches, with median values for AvC30 dropping, especially from 3.71 to 2.54 kt for the West area. Probably yet more important though are the summaries of OMs for which conservation performance is inadequate, which is provided by **Figure 7.** These likely disqualify BR1 and its associated tuning from further consideration, and possibly also BR2. However, BR3 (especially its BR3* modification) and BR4 would probably be considered to be providing adequate resource conservation performance in the light of the key uncertainties covered by the OMs of the now revised grid.

Robustness tests for BR3 show evidence of some instances of poor resource conservation performance (see Table 4 and Figure 8a), the worst being for Time varying mixing and Unreported overage. That such problems do occur is not entirely unexpected, as most of these tests are based on OM1 to OM4 for which such conservation performance is amongst the worst in the updated grid anyway (in part because these OMs correspond to the lowest abundance in absolute terms for both stocks., i.e. the - - scenarios). Time has prevented detailed consideration of the problematic instances and identification of the reasons why they occur, but it is evident that most of these instances are for recruitment scenario 2, for which the current status of the eastern stock is worse than for recruitment scenario 1.

Summary

An important implication of the results reported is that meeting the lower tuning targets leads to results for the "less productive resources" OMs that show questionably acceptable resource conservation behaviour. This is as reflected by Br30 values that are well below 1, and can at times even reflect instances of resource extirpation.

Essentially only the BR4 and BR3 (perhaps with an initial cap on West area TACs) perform adequately in this resource conservation regard. Eastern stock tunings of less than about 1.5 need to be excluded from further consideration, unless the Working Group agrees that certain "difficult" OMs should be regarded as of sufficiently low plausibility that such performance by a CMP in their regard can nevertheless be considered to meet acceptability thresholds. Tuning targets for the western stock which are lower than 1.5 are indicated to still be providing acceptable performance; this target could be reduced to below 1.25 and perhaps even somewhat lower than that for that stock.

Even so, resource conservation performance for the BR3 CMP (eastern tuning 1.5; western tuning 1.25) is unsatisfactory for some robustness tests, and the Working Group needs to give special attention to the how plausible these scenarios might be considered to be.

It is anticipated that the BR CMP might be somewhat further refined in the light of discussions at the July 2021 BFT MSE meeting.

References

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.

ICCAT. 2021. Report of the first 2021 Intersessional Meeting of the Bluefin Tuna Species Group (including W-BFT data preparatory) (Online, 5-13 April 2021). 86 pp.

Table 1. Control parameter values for each of the CMPs presented here.

	Tuned to median Br30						Eastern caps			Western caps	
CMP name	East	West	α	β	γ	$s^{threshold}$	To 2030	>2030	Whole period	To 2030	>2030
BR1	1.00	1.00	7.00	1.24	10	0	<40 000t	<50 000t	>12 000t	-	-
BR2	1.25	1.25	3.32	0.91	10	0	<36 000t	<45 000t	>12 000t	-	-
BR2*	1.25	1.25	3.30	0.92	10	0	<36 000t	<45 000t	>12 000t	<2 350t	-
BR3	1.50	1.25	1.72	0.94	10	0	<36 000t	<45 000t	>12 000t	-	-
BR3*	1.50	1.25	1.69	0.95	10	0	<36 000t	<45 000t	>12 000t	<2 350t	-
BR4	1.50	1.50	1.70	0.66	10	0	<36 000t	<45 000t	>12 000t	-	-

Table 2. Deterministic Br30 and AvC30 values (median of the RS) for all six BR CMPs, 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	2.99 (2.51; 3.47)	0.00 (0.00; 0.00)	3.30 (2.75; 3.49)	0.00 (0.00; 0.00)	2.63 (2.48; 3.03)	0.00 (0.00; 0.00)	3.28 (2.75; 3.48)	0.00 (0.00; 0.00)
BR1	**1.00** (0.20; 2.19)	46.83 (18.09; 46.87)	1.83 (1.10; 2.39)	46.87 (46.87; 46.87)	0.78 (0.47; 1.03)	25.22 (16.62; 38.61)	0.89 (0.11; 1.56)	46.83 (38.07; 46.87)
BR2	**1.25** (0.46; 2.30)	41.47 (17.46; 42.18)	1.98 (1.35; 2.49)	42.18 (42.18; 42.18)	1.03 (0.81; 1.23)	26.64 (16.22; 34.27)	1.22 (0.36; 1.77)	41.47 (32.40; 41.91)
BR2*	**1.25** (0.45; 2.31)	41.46 (17.80; 42.18)	1.98 (1.35; 2.50)	42.18 (42.18; 42.18)	1.03 (0.80; 1.22)	26.61 (16.55; 34.28)	1.23 (0.36; 1.78)	41.46 (32.46; 41.92)
BR3	**1.50** (0.79; 2.30)	38.16 (15.88; 42.18)	2.02 (1.53; 2.49)	42.18 (37.72; 42.18)	1.34 (1.13; 1.53)	21.91 (14.98; 29.35)	1.43 (0.55; 1.93)	38.38 (28.05; 40.36)
BR3*	**1.50** (0.80; 2.31)	38.11 (16.08; 42.18)	2.03 (1.54; 2.50)	42.18 (37.55; 42.18)	1.34 (1.13; 1.54)	21.80 (15.08; 29.27)	1.44 (0.57; 1.94)	38.33 (27.89; 40.34)
BR4	**1.50** (0.80; 2.32)	38.14 (16.34; 42.18)	2.04 (1.54; 2.50)	42.18 (37.66; 42.18)	1.34 (1.14; 1.54)	22.11 (15.21; 29.75)	1.44 (0.58; 1.95)	38.36 (27.96; 40.41)
WEST								
Zero catch	3.05 (1.94; 3.56)	0.00 (0.00; 0.00)	3.33 (3.06; 3.59)	0.00 (0.00; 0.00)	2.18 (1.91; 2.53)	0.00 (0.00; 0.00)	3.07 (2.77; 3.29)	0.00 (0.00; 0.00)
BR1	**1.00** (0.36; 2.00)	3.76 (1.67; 5.03)	1.43 (0.85; 2.05)	4.22 (3.55; 5.14)	0.66 (0.36; 1.47)	2.27 (1.04; 2.88)	0.84 (0.36; 1.70)	3.92 (3.25; 4.90)
BR2	**1.25** (0.61; 2.21)	3.24 (1.51; 4.57)	1.66 (1.02; 2.28)	3.65 (2.95; 4.66)	0.93 (0.57; 1.65)	2.00 (1.13; 2.49)	1.12 (0.61; 1.93)	3.43 (2.77; 4.49)
BR2*	**1.25** (0.55; 2.25)	2.90 (1.49; 3.73)	1.67 (1.07; 2.32)	3.15 (2.74; 3.83)	0.92 (0.56; 1.65)	2.01 (1.20; 2.49)	1.13 (0.49; 1.98)	3.02 (2.63; 3.68)
BR3	**1.24** (0.64; 2.20)	3.27 (1.60; 4.58)	1.66 (1.02; 2.27)	3.70 (3.01; 4.68)	0.94 (0.59; 1.66)	2.09 (1.23; 2.60)	1.12 (0.65; 1.92)	3.49 (2.84; 4.51)
BR3*	**1.25** (0.60; 2.24)	2.93 (1.57; 3.74)	1.66 (1.07; 2.31)	3.18 (2.79; 3.84)	0.93 (0.59; 1.66)	2.11 (1.37; 2.60)	1.13 (0.58; 1.97)	3.06 (2.68; 3.69)
BR4	**1.50** (0.86; 2.47)	2.51 (1.23; 3.81)	1.89 (1.28; 2.50)	2.95 (2.31; 3.83)	1.15 (0.80; 1.83)	1.69 (1.15; 2.05)	1.37 (0.89; 2.16)	2.83 (2.22; 3.75)

Table 3. Stochastic Br30 and AvC30 values (median of the RS) for all six BR CMPs, 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	2.89 (1.69; 3.77)	0.00 (0.00; 0.00)	3.14 (2.40; 4.01)	0.00 (0.00; 0.00)	2.24 (1.51; 3.39)	0.00 (0.00; 0.00)	2.02 (1.25; 2.93)	0.00 (0.00; 0.00)
BR1	0.83 (0.00; 2.30)	45.44 (15.12; 46.87)	1.72 (0.58; 2.65)	46.87 (42.79; 46.87)	0.41 (0.00; 1.27)	14.81 (10.22; 25.27)	0.47 (0.00; 1.60)	46.35 (34.98; 46.87)
BR2	1.22 (0.22; 2.45)	39.98 (12.94; 42.18)	1.87 (1.00; 2.76)	42.18 (36.19; 42.18)	0.90 (0.19; 1.78)	14.96 (10.27; 24.43)	0.78 (0.06; 1.89)	40.55 (29.06; 42.18)
BR2*	1.22 (0.21; 2.46)	40.32 (13.04; 42.18)	1.88 (0.94; 2.78)	42.18 (37.17; 42.18)	0.91 (0.09; 1.79)	14.81 (10.32; 23.93)	0.78 (0.17; 1.85)	40.65 (30.13; 42.18)
BR3	1.45 (0.48; 2.48)	35.59 (11.45; 42.18)	1.91 (1.23; 2.83)	42.18 (29.70; 42.18)	1.18 (0.60; 2.14)	17.48 (11.75; 29.85)	0.81 (0.06; 1.87)	37.57 (24.16; 41.19)
BR3*	1.47 (0.54; 2.49)	35.99 (11.41; 42.18)	1.93 (1.27; 2.82)	42.18 (30.01; 42.18)	1.20 (0.66; 2.18)	17.67 (11.75; 30.55)	0.86 (0.26; 1.88)	37.87 (24.08; 41.11)
BR4	1.47 (0.50; 2.49)	35.70 (11.53; 42.18)	1.94 (1.23; 2.84)	42.18 (30.21; 42.18)	1.19 (0.64; 2.17)	20.10 (12.45; 34.82)	1.01 (0.41; 2.07)	37.80 (24.82; 41.38)
WEST								
Zero catch	2.65 (1.47; 3.97)	0.00 (0.00; 0.00)	3.13 (2.44; 4.47)	0.00 (0.00; 0.00)	3.00 (2.23; 3.67)	0.00 (0.00; 0.00)	2.73 (2.12; 3.42)	0.00 (0.00; 0.00)
BR1	0.73 (0.00; 1.96)	3.71 (1.08; 5.51)	1.17 (0.40; 2.44)	4.26 (3.28; 5.86)	0.69 (0.00; 1.60)	1.57 (0.94; 2.50)	0.51 (0.00; 1.58)	4.10 (3.15; 5.61)
BR2	1.01 (0.13; 2.25)	3.26 (1.08; 5.06)	1.41 (0.63; 2.80)	3.71 (2.74; 5.29)	0.99 (0.13; 1.82)	1.56 (0.83; 2.34)	0.82 (0.08; 1.85)	3.58 (2.67; 5.24)
BR2*	1.20 (0.27; 2.42)	2.55 (1.08; 3.75)	1.65 (0.82; 2.94)	2.95 (2.25; 4.01)	0.99 (0.13; 1.83)	1.58 (0.72; 2.27)	1.08 (0.21; 2.06)	2.84 (2.20; 3.78)
BR3	1.04 (0.20; 2.23)	3.32 (1.16; 5.01)	1.43 (0.67; 2.69)	3.81 (2.86; 5.24)	1.22 (0.31; 1.95)	1.67 (0.89; 2.39)	0.86 (0.14; 1.83)	3.67 (2.76; 5.14)
BR3*	1.26 (0.33; 2.51)	2.57 (1.14; 3.73)	1.67 (0.80; 2.92)	2.93 (2.22; 3.91)	1.25 (0.35; 1.95)	1.66 (0.73; 2.29)	1.12 (0.29; 2.09)	2.87 (2.16; 3.79)
BR4	1.32 (0.45; 2.53)	2.54 (0.96; 4.03)	1.69 (0.92; 3.01)	2.94 (2.14; 4.21)	1.25 (0.32; 1.97)	1.37 (0.71; 1.98)	1.11 (0.38; 2.11)	2.84 (2.09; 4.16)

Table 4. Stochastic median and 90%iles Br30 and AvC30 values (across the four OMs for each robustness test) for BR3 CMPs. AvC30 values are in '000 mt. The number of instances (out of four OMs) for which a) the lower 5%ile Br30 falls below 0.1, b) the median Br30 falls below 0.2 and c) the median Br30 is zero are also given. See Table 5 below for an explanation of the abbreviations used to describe each test. Note that the results for the Intermediate parameter test have been omitted, as a coding error in those trials has been detected.

	Br30		AvC30		5%<0.1	Median <0.2	Median =0
EAST							
WstGw	1.47	(0.51; 2.05)	27.16	(9.96; 42.18)	0	0	0
Qinc	1.29	(0.44; 1.91)	34.01	(11.43; 42.18)	0	0	0
CatOver	1.30	(0.44; 1.81)	25.81	(11.05; 50.62)	0	0	0
HiWmix	1.44	(0.66; 2.01)	27.29	(10.32; 42.18)	0	0	0
BrzCt	1.39	(0.71; 2.07)	27.92	(10.26; 42.18)	0	0	0
TVmix	1.30	(0.00; 2.05)	32.83	(10.79; 42.18)	1	1	1
NLindex	1.49	(0.68; 2.06)	27.80	(10.40; 42.18)	0	0	0
PChgMix	1.44	(0.20; 2.31)	32.71	(10.15; 42.18)	1	0	0
TVregime	0.89	(0.45; 1.62)	35.76	(21.45; 42.18)	0	0	0
IntPar							
ZeroEmix	1.77	(1.19; 3.74)	34.40	(18.89; 42.18)	0	0	0
WEST							
WstGw	0.73	(0.27; 1.29)	2.78	(1.12; 4.30)	0	0	0
Qinc	0.44	(0.00; 0.93)	3.33	(0.88; 5.97)	1	1	0
CatOver	0.54	(0.00; 1.17)	2.78	(0.82; 5.18)	1	1	1
HiWmix	0.80	(0.01; 1.59)	2.57	(0.82; 4.20)	1	1	0
BrzCt	0.72	(0.03; 1.51)	2.63	(0.83; 4.37)	1	1	0
TVmix	0.68	(0.00; 1.46)	2.59	(0.83; 5.04)	1	1	0
NLindex	0.71	(0.00; 1.39)	2.67	(0.82; 4.81)	0	0	0
PChgMix	1.02	(0.18; 2.03)	2.65	(0.85; 5.40)	0	0	0
TVregime	0.38	(0.08; 0.80)	3.83	(3.11; 4.67)	2	0	0
IntPar							
ZeroEmix	0.82	(0.41; 1.35)	2.18	(1.13; 3.22)	0	0	0

Table 5. Robustness tests abbreviations and descriptions.

Abbreviation	
WstGw	**Western stock growth curve for eastern stock.**
Qinc	**Catchability Increases**. CPUE-based indices are subject to a 2% annual increase in catchability in the future.
CatOver	**Unreported overages.** Future catches in both the West and East areas are 20% larger than the TAC as a result of IUU fishing (not known and hence not accounted for by the CMP).
HiWmix	**High western mixing.** The old mixing axis factor level 2: 20% western stock biomass in East area on average from 1965-2016.
BrzCt	**'Brazilian catches'.** Catches in the South Atlantic, including relatively high takes during the 1950s and 60s, are reallocated from the western stock to the eastern stock.
TVmix	**Time varying mixing**. Eastern stock mixing alternates between 2.5%and 7.5% every three years.
NLindex	**Non-linear indices.** Hyperstability in OM fits to data is simulated in projection years for all indices.
PChgMix	**Persistent change in mixing.** Eastern mixing increases from 2.5% to 7.5% after 10 years.
TVregime	**Varying time of regime change in R3.**
IntPar	**Intermediate parameter levels** for M, growth, maturity, scale, regime shifts.
ZeroEmix	**Zero eastern stock mixing**. No Eastern stock in the West area.

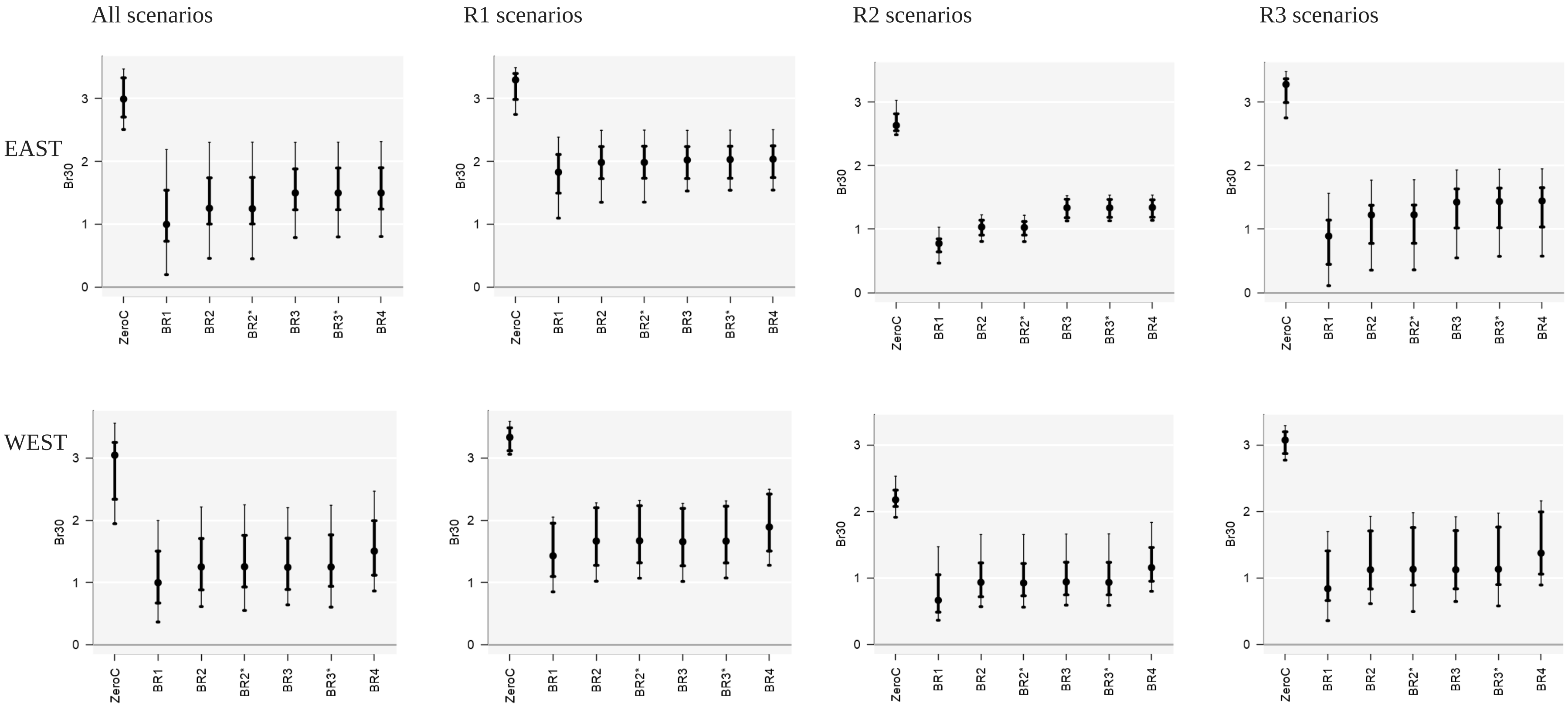


Figure 1a. **Deterministic Br30** values for zero catch and the CMPs considered over the interim grid of OMs for CMPs BR1 to BR4, first for all OMs in the interim grid ("All scenarios"), and then for each of the recruitment scenarios separately, showing median, interquartile and 90%-ile ranges.

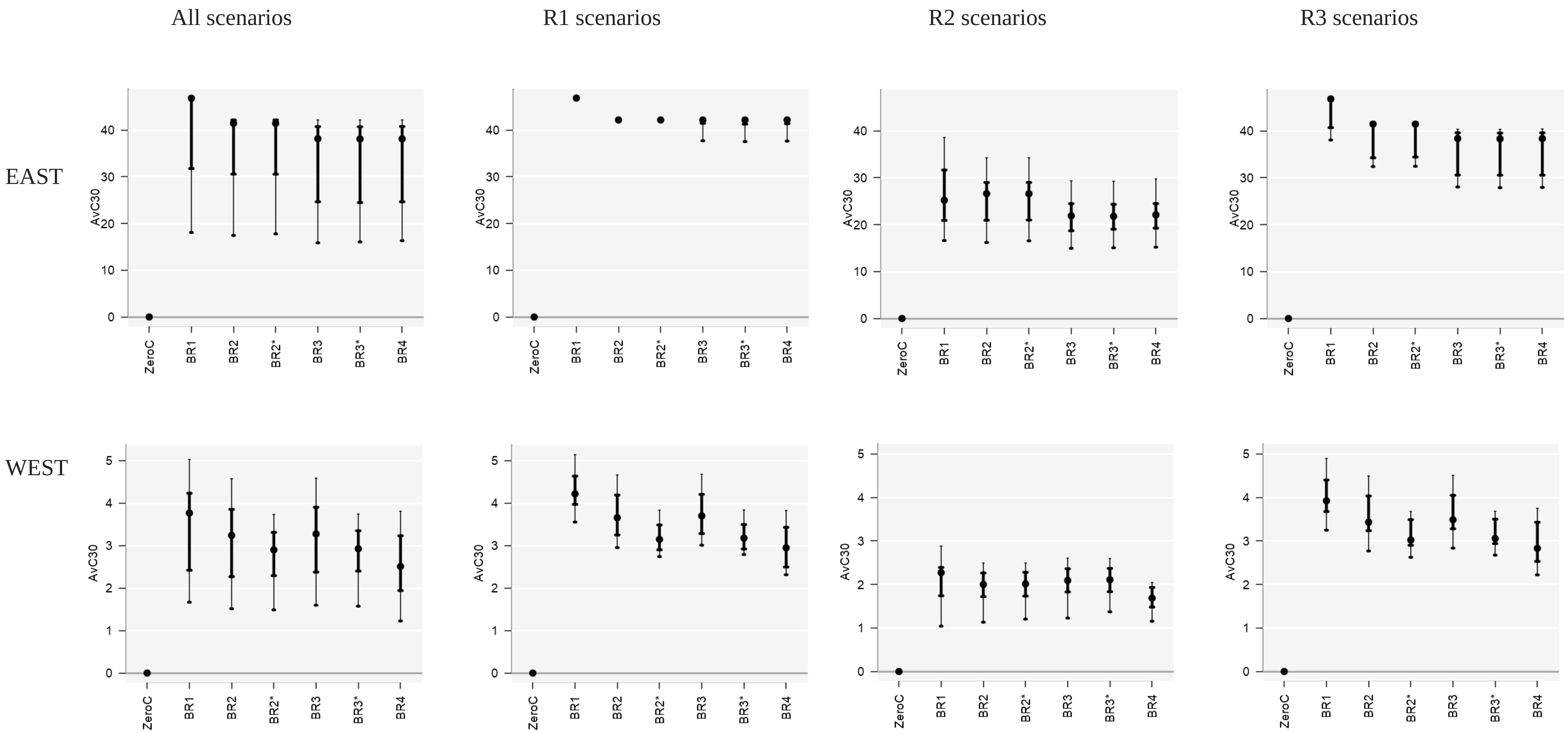


Figure 1b. **Deterministic AvC30** values for zero catch and the CMPs considered over the interim grid of OMs for CMPs BR1 to BR4, first for all OMs in the interim grid ("All scenarios"), and then for each of the recruitment scenarios separately, showing median, interquartile and 90%-ile ranges.

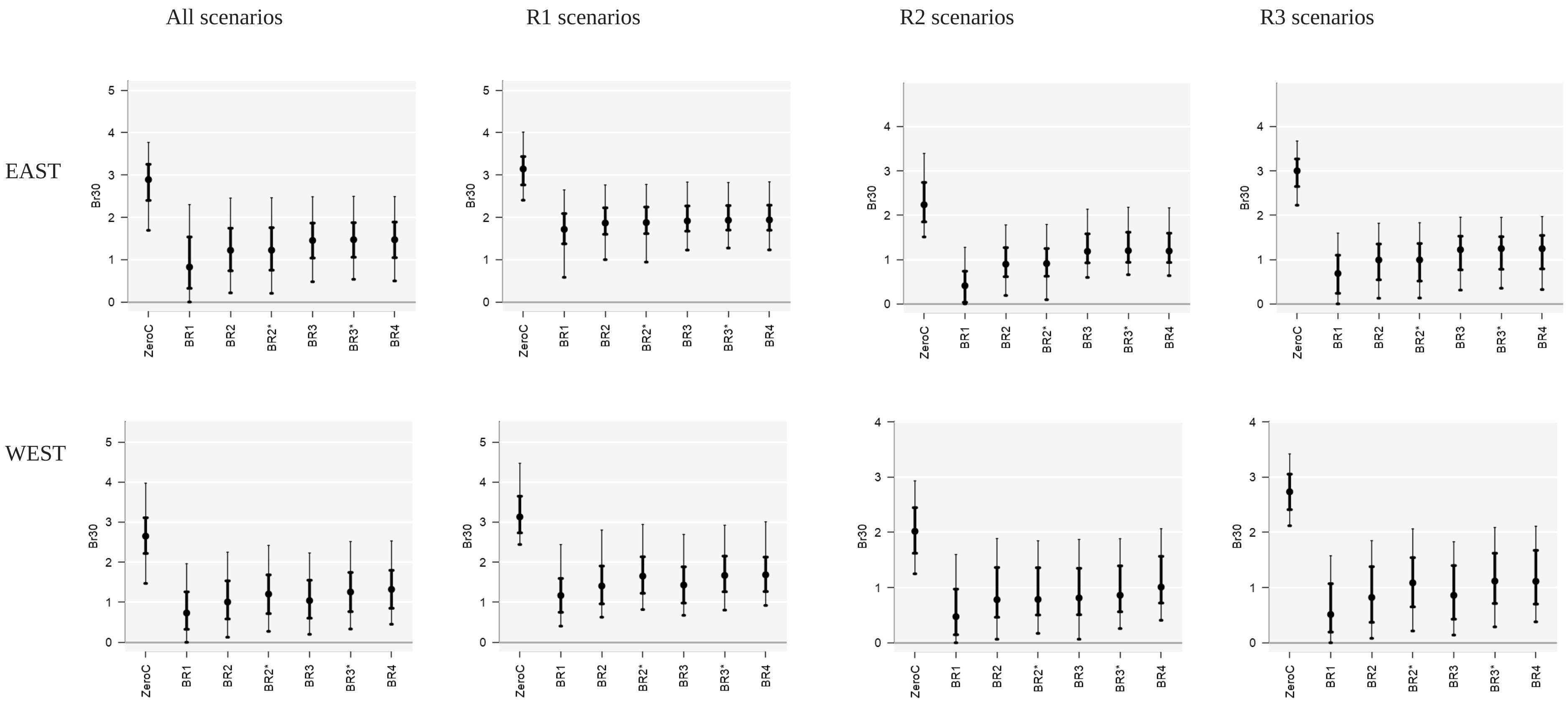


Figure 2a. **Stochastic Br30** values for zero catch and the CMPs considered over the interim grid of OMs for CMPs BR1 to BR4, first for all OMs in the interim grid ("All scenarios"), and then for each of the recruitment scenarios separately, showing median, interquartile and 90%-ile ranges.

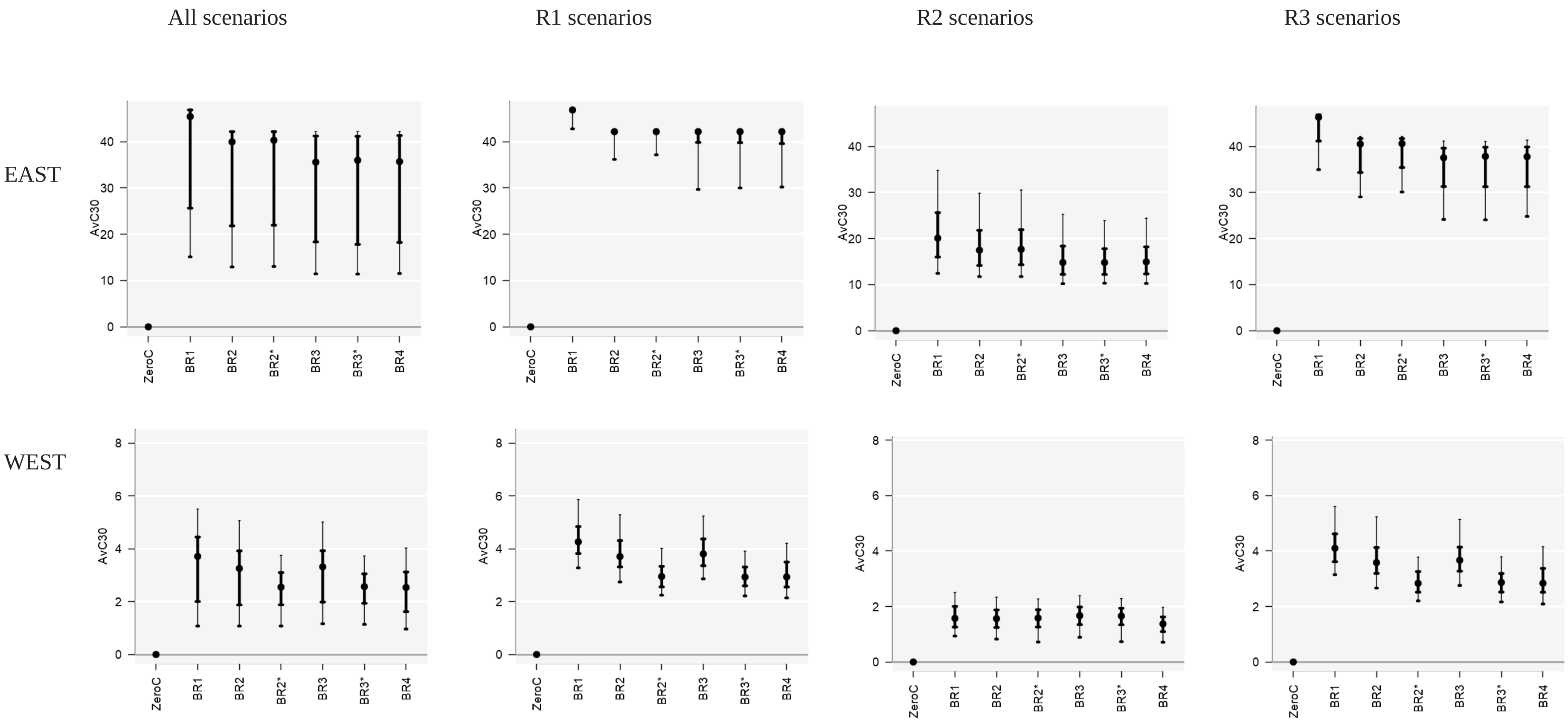


Figure 2b. Stochastic AvC30 values for zero catch and the CMPs considered over the interim grid of OMs for CMPs BR1 to BR4, first for all OMs in the interim grid ("All scenarios"), and then for each of the recruitment scenarios separately, showing median, interquartile and 90%-ile ranges).

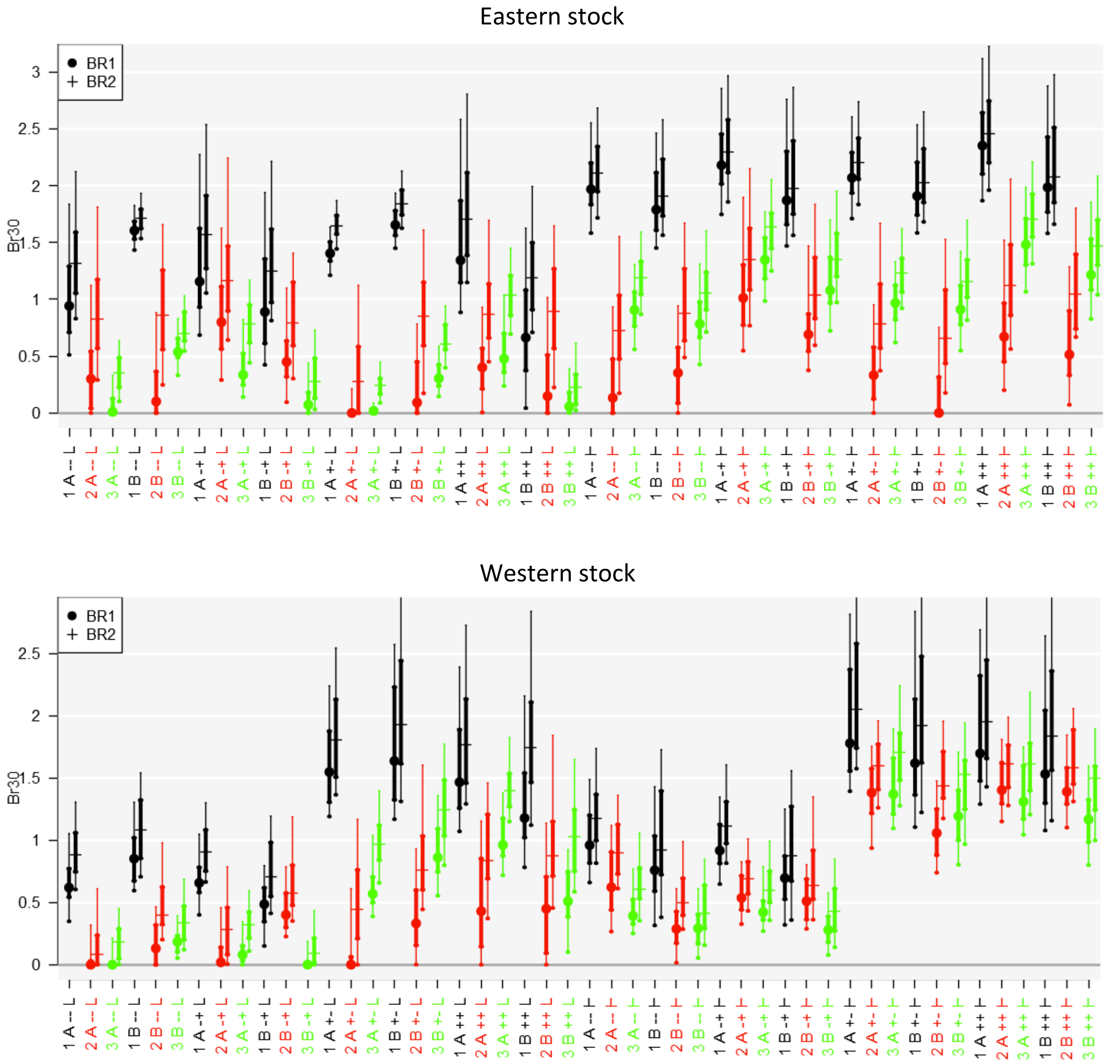


Figure 3a. **Stochastic Br30** results for **BR1** (1.00 East-1.00 West tuning) and **BR2** (1.25 East-1.25 West tuning). The three colours correspond to the three recruitment scenarios: black, red and green to R1, R2 and R3 respectively.

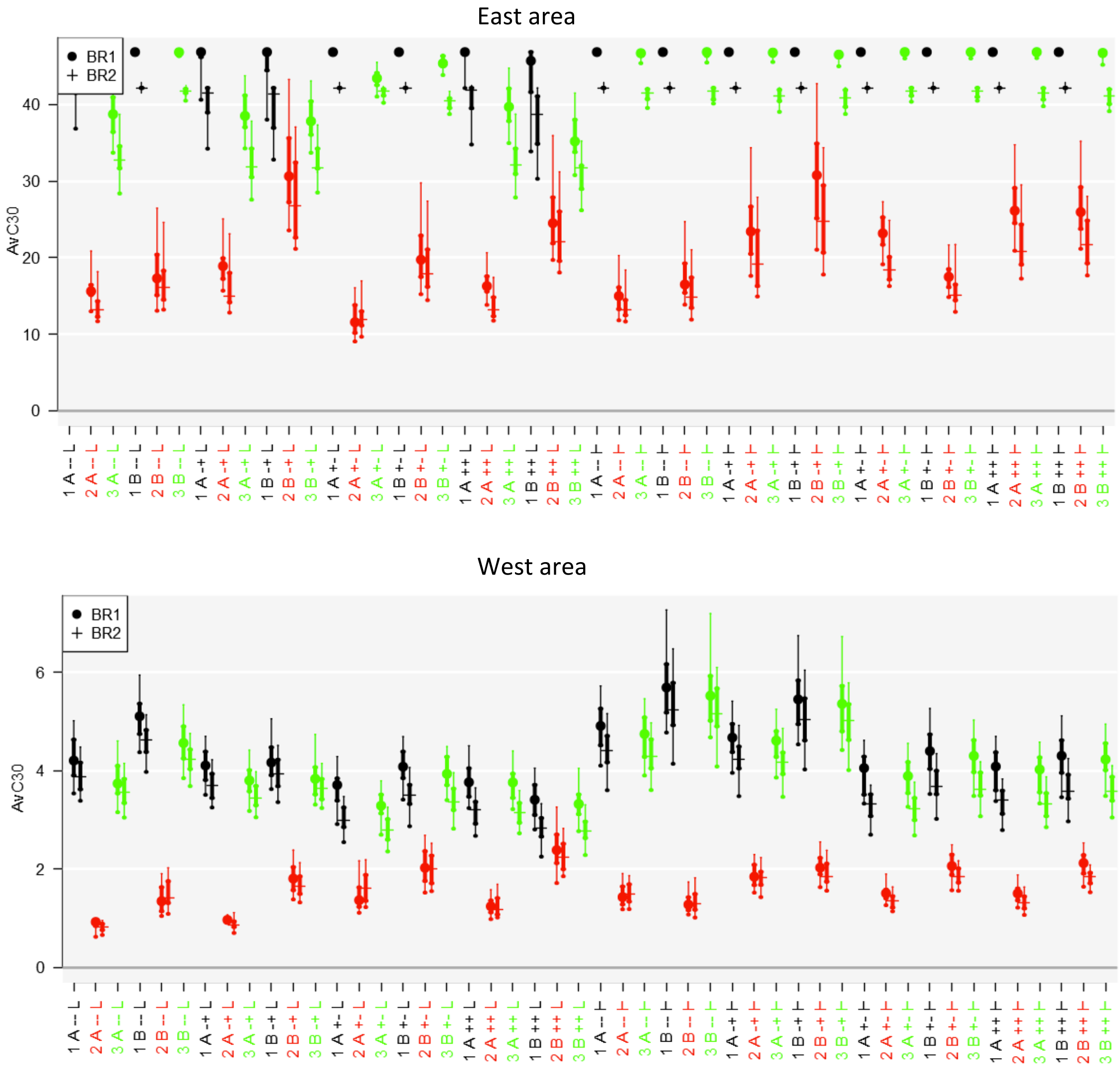


Figure 3b. **Stochastic AvC30** results for **BR1** (1.00 East-1.00 West tuning) and **BR2** (1.25 East-1.25 West tuning). The three colours correspond to the three recruitment scenarios: black, red and green to R1, R2 and R3 respectively.

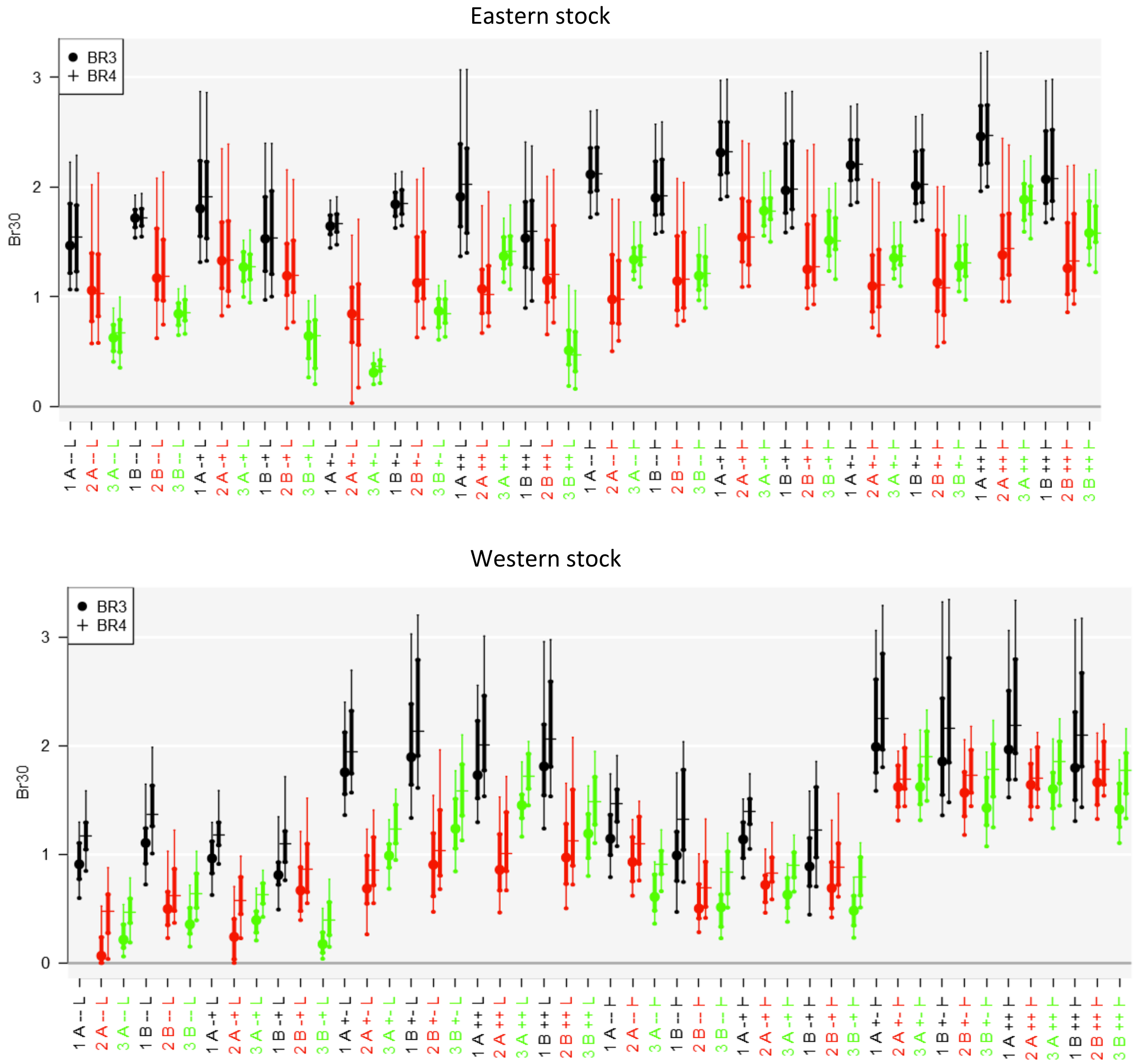


Figure 4a. **Stochastic Br30** results for **BR3** (1.50 East-1.25 West tuning) and **BR4** (1.50 East-1.50 West tuning). The three colours correspond to the three recruitment scenarios: black, red and green to R1, R2 and R3 respectively

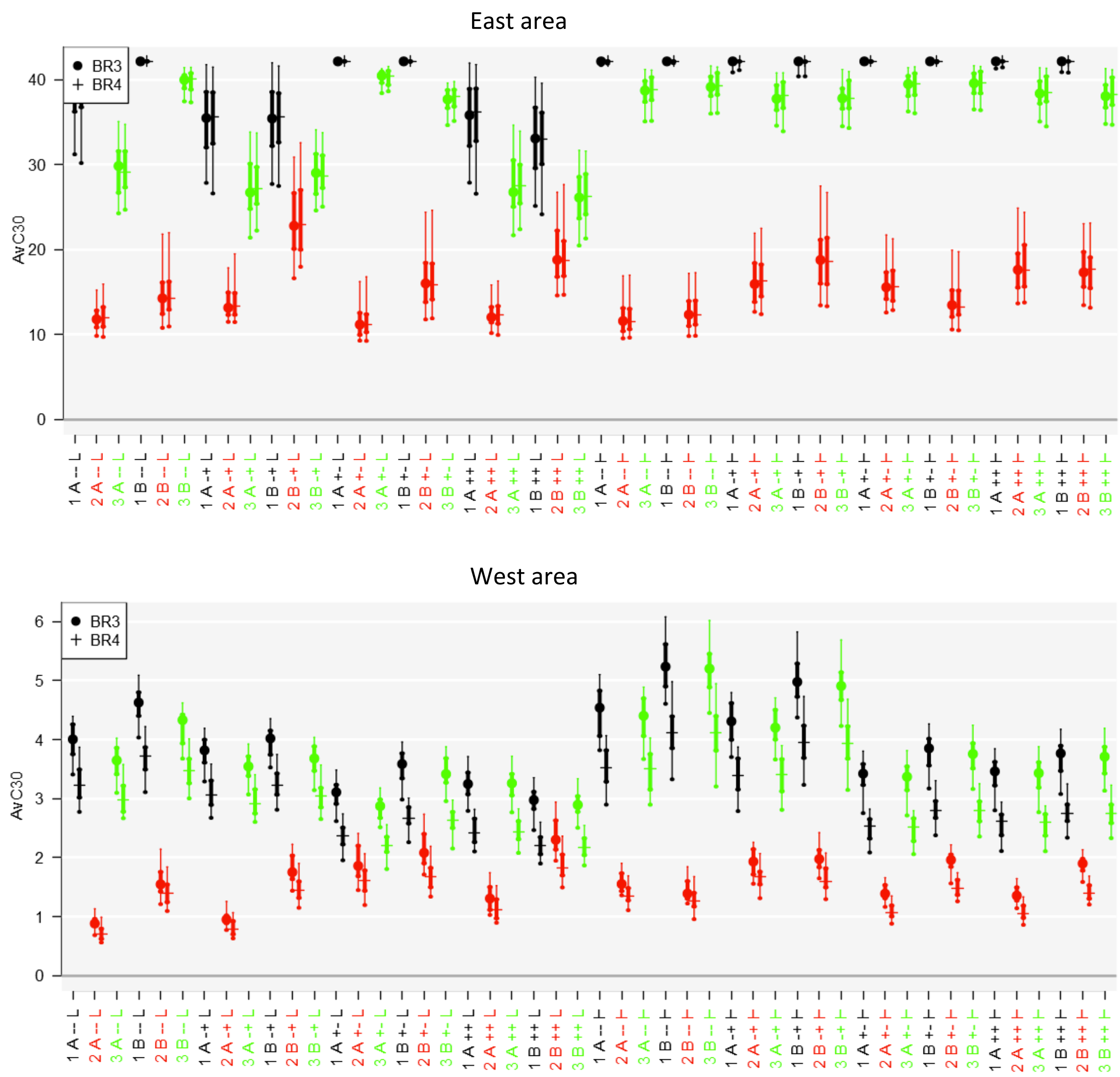


Figure 4b: **Stochastic AvC30** results for **BR3** (1.50 East-1.25 West tuning) and **BR4** (1.50 East-1.50 West tuning). The three colours correspond to the three recruitment scenarios: black, red and green to R1, R2 and R3 respectively

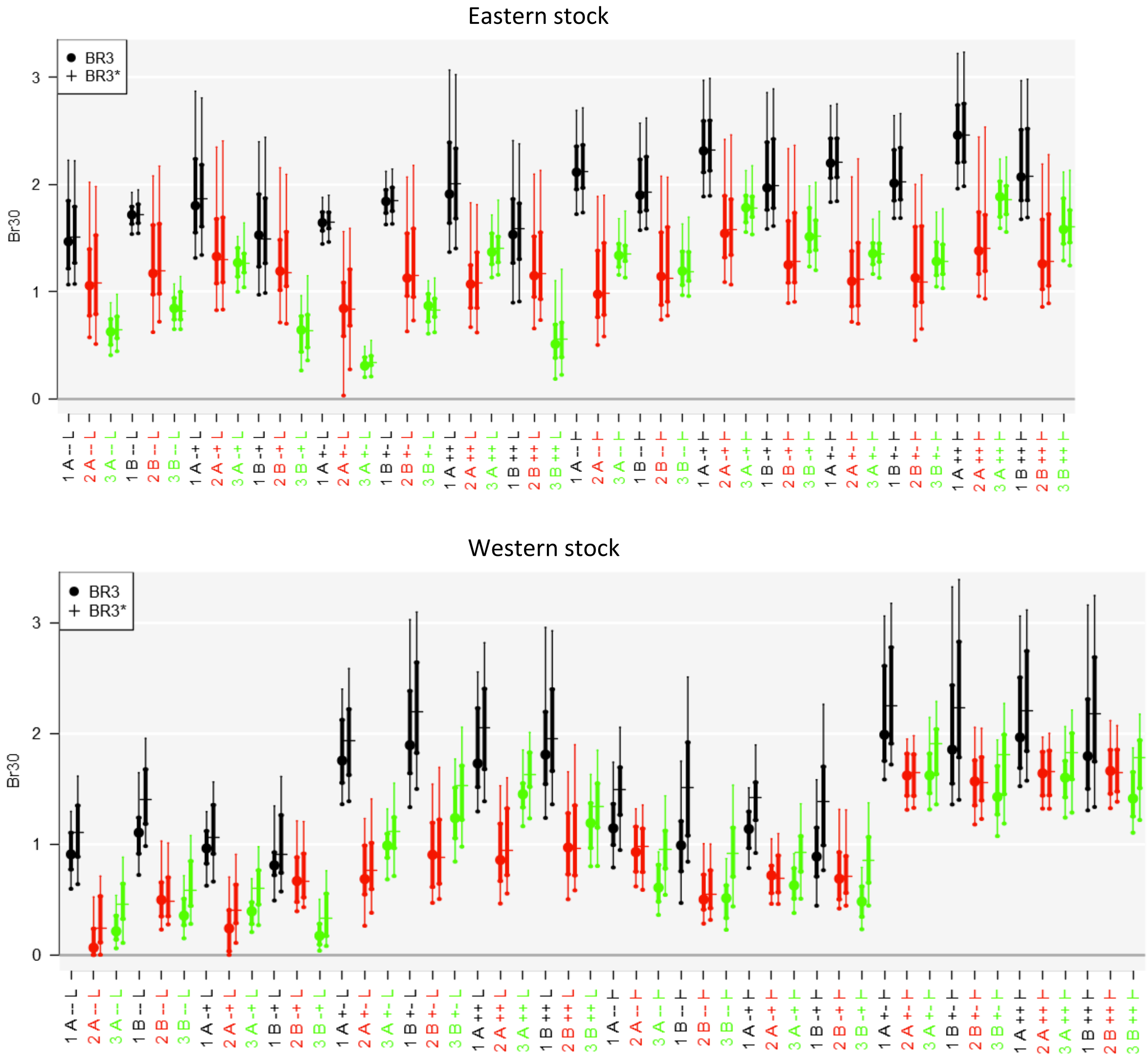
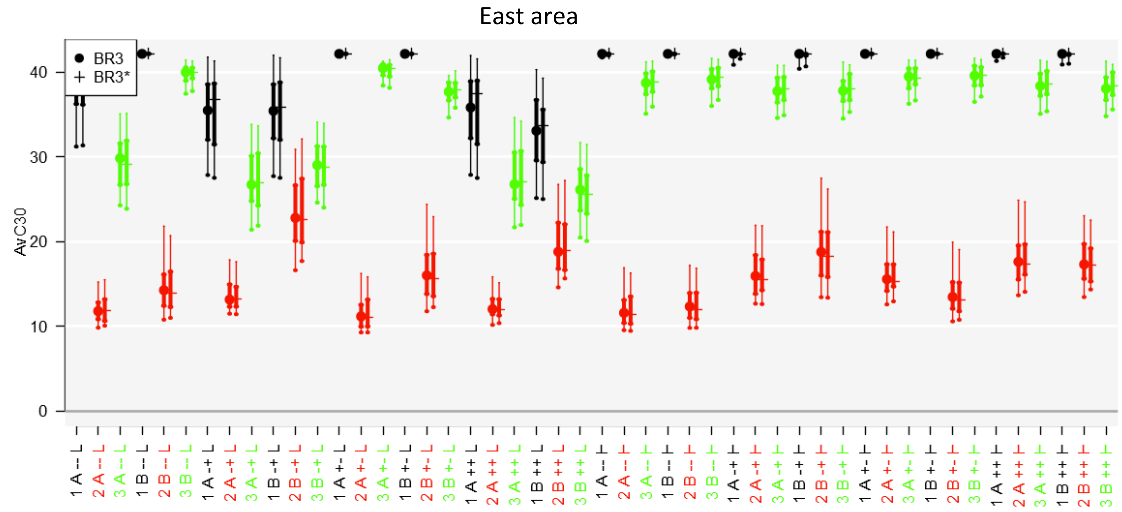


Figure 5a: **Stochastic Br30** results for **BR3** (1.50 East-1.25 West tuning, no cap in the West) and **BR3*** (1.50 East-1.25 West tuning, with cap in the West). The three colours correspond to the three recruitment scenarios: black, red and green to R1, R2 and R3 respectively



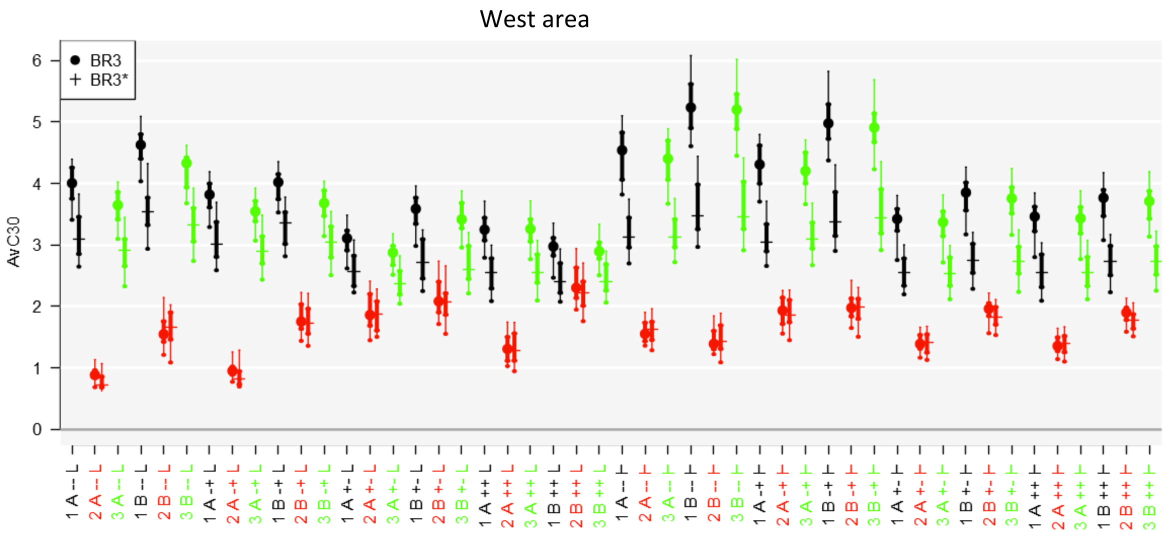


Figure 5b: **Stochastic AvC30** results for **BR3** (1.50 East-1.25 West tuning, no cap in the West) and **BR3*** (1.50 East-1.25 West tuning, with cap in the West). The three colours correspond to the three recruitment scenarios: black, red and green to R1, R2 and R3 respectively.

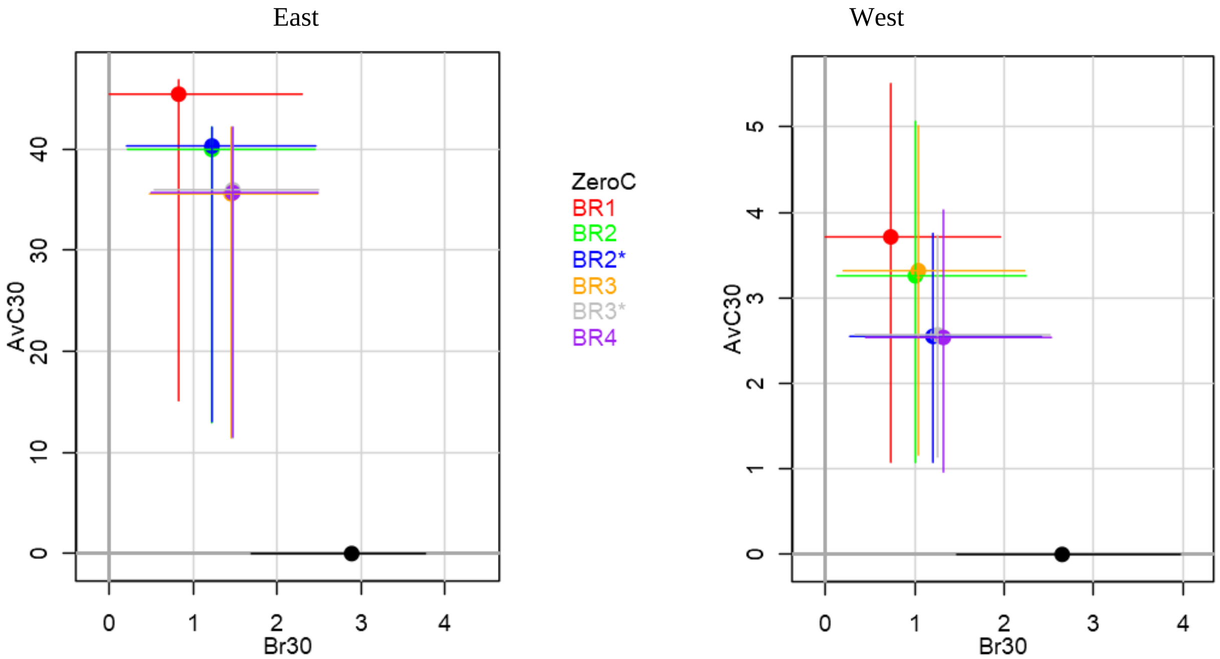


Figure 6: A trade-off plot showing mean and 90%-ile range performance over the interim grid of OMs for stochastic simulations for CMPs BR1 to BR4. Note that in some cases performance is sufficiently similar that the plots for two CMPs show the one set of results overlapping and "hiding" the other.

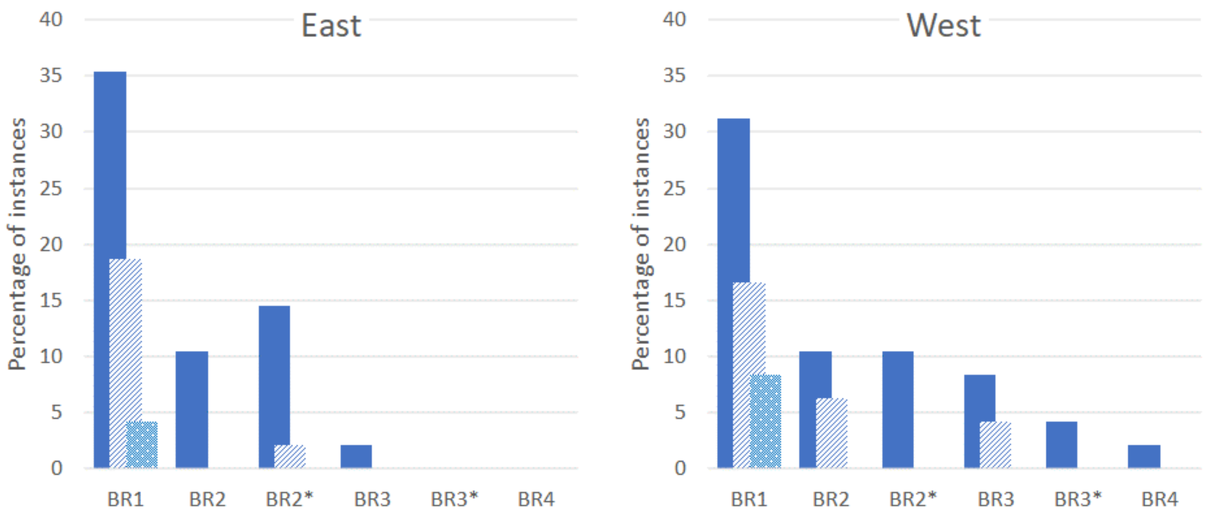


Figure 7a: For each CMP and for the stochastic results, the percentage of instances (**all recruitment scenarios, i.e. out of 48 OMs**) is shown that a) the lower 5%ile Br30 falls below 0.1 (full columns), b) the median Br30 falls below 0.2 (diagonal dashed columns) and c) the median Br30 is zero (dotted columns).

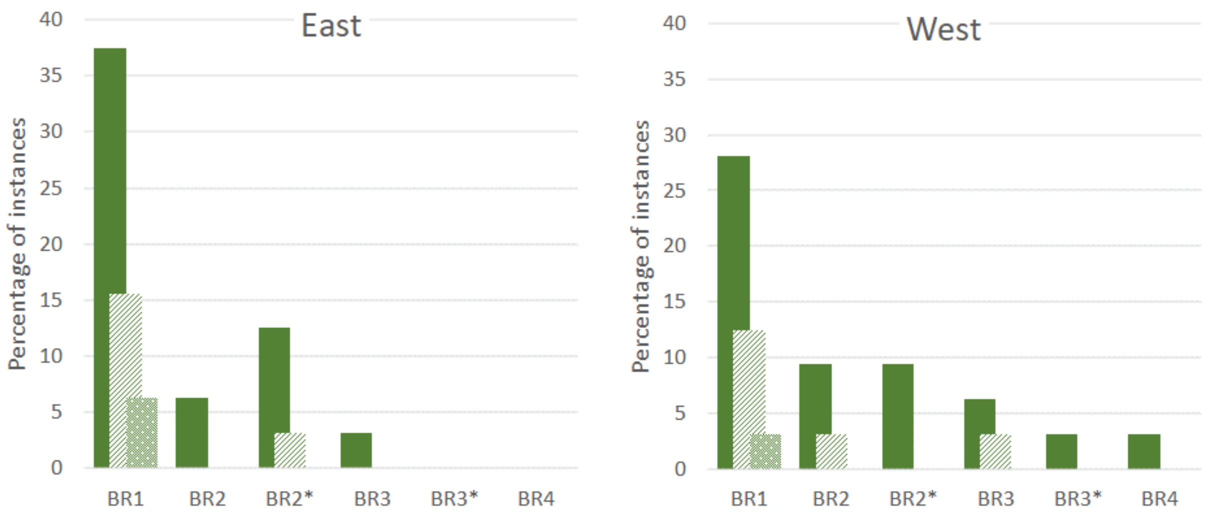


Figure 7b: For each CMP and for the stochastic results, the percentage of instances (**recruitment scenarios 1 and 2 only, i.e. out of 32 OMs**) is shown that a) the lower 5%ile Br30 falls below 0.1 (full columns), b) the median Br30 falls below 0.2 (diagonal dashed columns) and c) the median Br30 is zero (dotted columns).

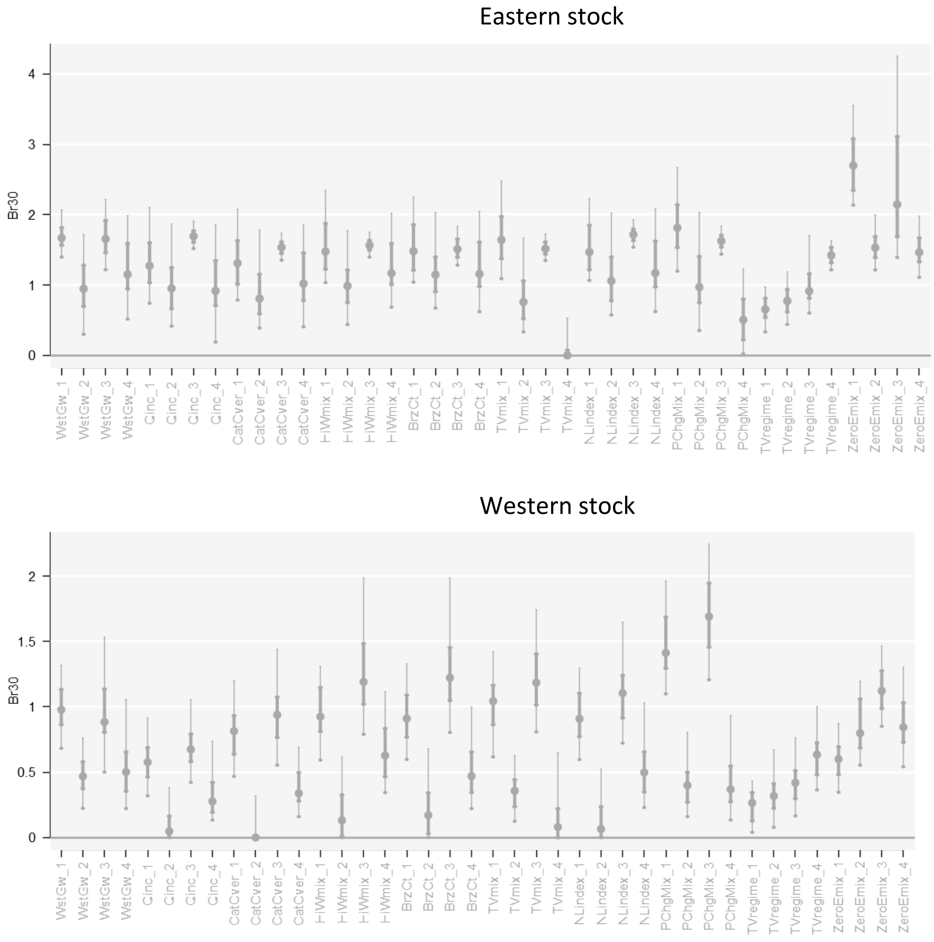
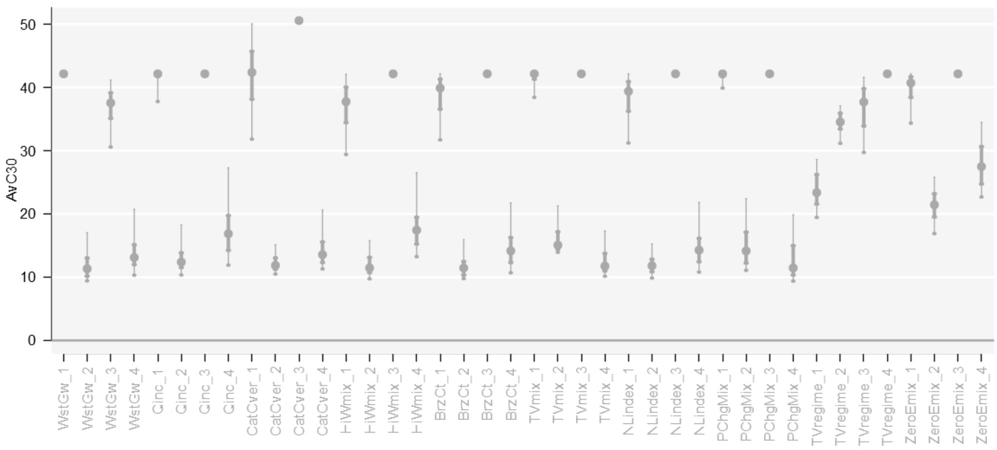


Figure 8a: **Stochastic Br30** results for **BR3** for the robustness tests.

WstGw	Western stock growth curve for eastern stock.
Qinc	Catchability Increases.
CatOver	Unreported overages.
HiWmix	High western mixing.
BrzCt	'Brazilian catches'.
TVmix	Time varying mixing.
NLindex	Non-linear indices.
PChgMix	Persistent change in mixing.
TVregime	Varying time of regime change in R3.
IntPar	Intermediate parameter levels.
ZeroEmix	Zero eastern stock mixing.

East area



West area

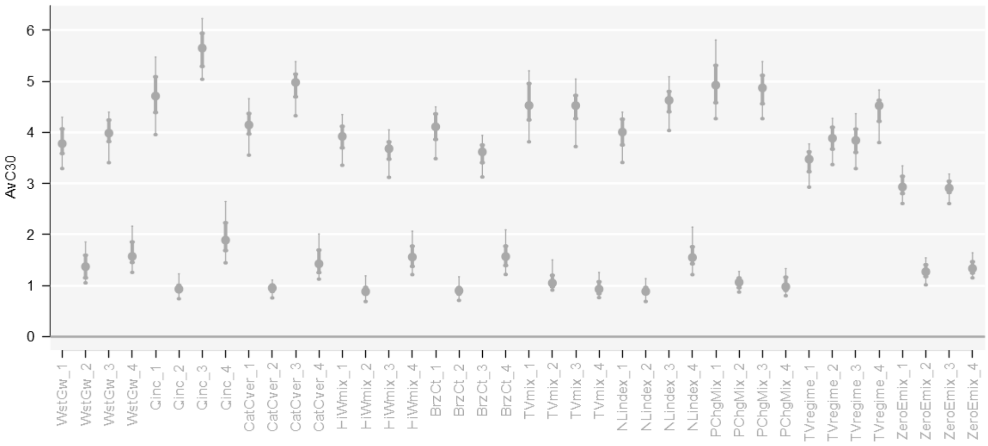


Figure 8b: **Stochastic AvC30** results for **BR3** for the robustness tests.

WstGw	Western stock growth curve for eastern stock.
Qinc	Catchability Increases.
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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*=4 for the East area and *n*=6 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”.

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, 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 MEXUS_GOM_PLL indices, 2010-2019 for JPN_LL_West2 and 2006-2017 for CAN_SWNS.

[3] For the aerial surveys, there is no value for 2013, (French) and 2018 (Mediterranean). These years were omitted from this averaging where relevant.Note also that the GBYP aerial survey has not been included at this stage.

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:

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

(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.

<u>Constraints on the extent of TAC increase and decrease</u>

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

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

where *D*= 0.3 in implementations.

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 for the East area, where TACs can otherwise rise to in excess of 70 kt, and in some instances for the West area as well.

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 (averaged over the OMs) values used in weighting when averaging over the indices to provide composite indices for the East and the West areas (see following equation A2).

EAST		WEST	
Index name	σ^i	Index name	σ^i
FR_AER_SUV2	1.00	GOM_LAR_SUV	0.52
MED_LAR_SUV	0.33	US_RR_66_144	0.33
MOR_POR_TRAP	0.56	US_RR_177	3.16
JPN_LL_NEAtl2	0.45	MEXUS_GOM_PLL2	0.47
		JPN_LL_West2	0.41
		CAN_SWNS	1.80

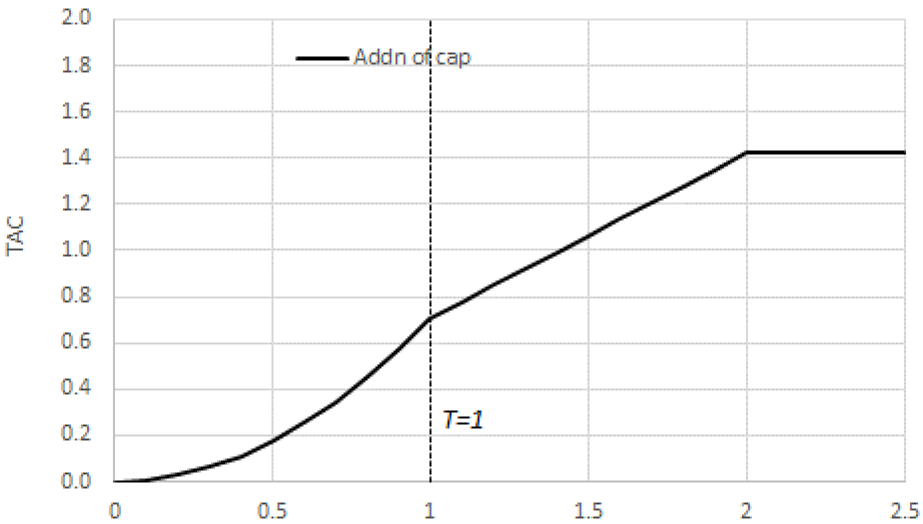

Figure A1. Illustrative relationship (the "catch control law") of *TAC* against $J_{av,y}$ for the BR CMPs, which includes the parabolic decrease below T and the capping of the TAC so as not to exceed some maximum value.