SCRS/2021/152 Collect. Vol. Sci. Pap. ICCAT, 78(3): 1073-1097 (2021)

REFINEMENTS OF THE BR CMP AS OF AUGUST 2021

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SUMMARY

The BR CMP is refined slightly, with the principal change being the removal of caps on the TACs in the East and West areas for the first 10 years of operation. These restrictions are replaced by limitations on the extent of TAC increase allowed; the limitations depend on the recent trend in the composite abundance index for the area in question. Deterministic and stochastic results are provided for the most recent set of tunings specified by the Bluefin Tuna MSE Technical Group.

RÉSUMÉ

La CMP BR a été légèrement affinée, le principal changement étant la suppression des plafonds des TAC dans les zones Est et Ouest pour les dix premières années de mise en œuvre. Ces restrictions sont remplacées par des limitations de l'ampleur de l'augmentation du TAC autorisée ; ces limitations dépendent de la tendance récente de l'indice composite d'abondance pour la zone en question. Les résultats déterministes et stochastiques sont fournis pour l'ensemble le plus récent de calibrages spécifiés par le Groupe de travail technique sur la MSE pour le thon rouge.

RESUMEN

Se ha refinado ligeramente el CMP BR, siendo el principal cambio la eliminación de límites a los TAC en las zonas occidental y oriental para los primeros 10 años de operación. Estas restricciones se han sustituido por limitaciones a la magnitud de incremento del TAC permitida, las limitaciones dependen de la tendencia reciente en el índice de abundancia compuesto para el área en cuestión. Se facilitan resultados deterministas y escolásticos para el conjunto más reciente de calibraciones especificado por el Grupo técnico sobre la MSE para el atún rojo.

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 weighted median Br30 values for the eastern and western stocks for deterministic runs of the (revised) interim grid OMs – see Table 1) as specified at the July 2021 intersessional meeting of the Bluefin Tuna MSE Technical Group (ICCAT, 2021) for the reconditioned OMs. Results are shown for both deterministic and stochastic runs. Deterministic results are also shown for the robustness test OMs.

Appendix A provides mathematical specifications for the refined BR CMP. The change from the BR CMPs presented in July, apart from changes in the parameter values, is in the maximum increase allowed from one TAC to the next in the East area. In previous versions, the maximum increase was fixed at 20%. It is now a function of the immediate past trend in the average index. If the trend is negative, the TAC is not allowed to increase. If the trend is greater then 0.1, the maximum increase is 20%; in between, the maximum increase is a linear function of the trend value. This change made it possible to remove the 10-year cap on the Eastern TAC that was a feature of the previous BR CMPs.

The package ABTMSE v7.3.2 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 BR0 (1.00 East – 1.00 West tuning) and BR1 (1.25 East – 1.25 West tuning) CMPs for each of the 48 OMs of the interim grid are compared in Figure 3, and similarly under BR2 (1.50 East – 1.25 West tuning) and BR3 (1.25 East – 1.50 West tuning) in Figure 4, and under BR3 and BR4 (1.50 East – 1.50 West tuning) 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.

Deterministic robustness tests' results under BR2 are given in Table 4 and plotted in Figure 8.

Discussion

We offer only a few initial general observations at this time.

- For the stochastic runs, the lower tunings give questionably acceptably performance in terms of Br30.
- However, BR2 and BR4 perform better in terms of lower 5%-iles for Br30.
- The loss in terms of AvC30 for these higher compared to the lower tunings is about 6000 mt in East area, and 500 mt in West area.
- There are nevertheless still a number of OMs for which resource conservation is poor in the stochastic trials, for which the population can be extirpated even for these higher tunings; all such instances correspond to R2 scenarios.

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 MSE Technical Group *(Online, 5-10 July 2021).* 25 pp.

Table 1. Control parameter values for each of the CMPs presented in this document.

	Tuned to weighted median Br30						Maximum change in TAC			East cap
							Down	Up		
CMP name	East	West	α	β	γ	$s^{threshold}$	East and West	East	West	
BR0	1.00	1.00	9.20	1.40	10	0	20%, up to 30% if average index falls below 2017 value	20%	20%	< 60 000t
BR1	1.25	1.25	9,62	1.34	10	0		0-20% depending on average index trend		< 53 000t
BR2	1.50	1.25	4.20	1.41	10	0				< 48 000t
BR3	1.25	1.50	9.67	0.83	10	0				< 53 000t
BR4	1.50	1.50	4.60	0.88	10	0				< 48 000t

Table 2: **Deterministic** Br30 and AvC30 values (weighted median over the grid) for all five 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	2.96 (2.51; 3.47)	0.00 (0.00; 0.00)	3.28 (2.51; 3.53)	0.00 (0.00; 0.00)	2.63 (2.52; 3.10)	0.00 (0.00; 0.00)	3.28 (2.51; 3.48)	0.00 (0.00; 0.00)
BR0	**1.00** (0.00; 2.08)	47.58 (19.19; 58.90)	1.55 (1.00; 2.27)	58.90 (47.58; 58.90)	0.59 (0.00; 1.09)	23.73 (17.22; 40.43)	0.82 (0.11; 1.57)	50.42 (36.25; 55.22)
BR1	**1.25** (0.01; 2.08)	44.19 (19.19; 58.90)	1.69 (1.32; 2.28)	58.90 (42.26; 58.90)	0.88 (0.00; 1.25)	24.41 (16.20; 35.58)	1.36 (0.66; 1.87)	45.34 (29.90; 51.71)
BR2	**1.50** (0.78; 2.51)	35.53 (15.46; 45.86)	2.03 (1.57; 2.63)	41.53 (37.31; 46.00)	0.98 (0.72; 1.50)	23.01 (14.92; 33.58)	1.69 (0.94; 2.21)	35.53 (25.85; 42.65)
BR3	**1.25** (0.01; 2.08)	44.24 (19.19; 58.90)	1.69 (1.32; 2.28)	58.90 (42.31; 58.90)	0.88 (0.00; 1.25)	24.38 (16.20; 35.61)	1.35 (0.66; 1.87)	45.35 (29.94; 51.73)
BR4	**1.50** (0.73; 2.51)	36.29 (16.02; 45.88)	2.00 (1.50; 2.63)	41.71 (38.66; 46.01)	0.95 (0.63; 1.43)	23.80 (15.66; 34.73)	1.60 (0.81; 2.18)	36.29 (27.39; 43.28)
WEST								
Zero catch	3.05 (1.92; 3.56)	0.00 (0.00; 0.00)	3.33 (3.06; 3.57)	0.00 (0.00; 0.00)	2.16 (1.90; 2.49)	0.00 (0.00; 0.00)	3.07 (2.71; 3.26)	0.00 (0.00; 0.00)
BR0	**1.00** (0.23; 2.64)	2.72 (1.25; 4.12)	1.59 (0.70; 2.68)	3.56 (2.20; 4.30)	0.43 (0.14; 1.35)	1.98 (1.17; 2.72)	1.00 (0.35; 2.26)	3.37 (2.32; 4.11)
BR1	**1.25** (0.46; 2.72)	2.46 (1.33; 3.82)	1.68 (1.00; 2.74)	3.29 (2.06; 3.88)	0.65 (0.30; 1.49)	1.91 (1.10; 2.46)	1.18 (0.62; 2.38)	3.22 (2.16; 3.78)
BR2	**1.25** (0.39; 2.70)	2.91 (1.92; 4.23)	1.72 (0.89; 2.71)	3.40 (2.12; 4.29)	0.54 (0.38; 1.36)	2.31 (1.39; 3.05)	1.25 (0.69; 2.34)	3.43 (2.29; 4.13)
BR3	**1.25** (0.45; 2.71)	2.47 (1.33; 3.84)	1.67 (0.99; 2.74)	3.31 (2.08; 3.90)	0.64 (0.29; 1.49)	1.91 (1.10; 2.47)	1.18 (0.61; 2.38)	3.23 (2.17; 3.79)
BR4	**1.50** (0.64; 2.85)	2.11 (1.58; 3.33)	1.97 (1.28; 2.88)	2.76 (1.61; 3.33)	0.87 (0.60; 1.65)	1.81 (1.28; 2.17)	1.43 (0.89; 2.54)	2.98 (1.73; 3.43)

Table 3: **Stochastic** Br30 and AvC30 values (weighted median over the grid) for all five 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	2.86 (1.69; 3.73)	0.00 (0.00; 0.00)	3.08 (2.40; 3.99)	0.00 (0.00; 0.00)	2.24 (1.51; 3.39)	0.00 (0.00; 0.00)	3.00 (2.23; 3.67)	0.00 (0.00; 0.00)
BR0	0.85 (0.00; 2.09)	45.74 (13.85; 58.90)	1.52 (0.75; 2.47)	58.90 (36.99; 58.90)	0.16 (0.00; 1.27)	19.73 (11.70; 34.54)	0.74 (0.00; 1.46)	49.90 (28.91; 56.68)
BR1	1.13 (0.00; 2.20)	42.34 (13.71; 58.90)	1.60 (0.85; 2.51)	58.90 (32.52; 58.90)	0.53 (0.00; 1.54)	18.64 (12.23; 31.97)	1.07 (0.00; 1.73)	45.61 (24.05; 53.52)
BR2	1.45 (0.20; 2.45)	34.87 (12.17; 46.74)	1.88 (1.34; 2.80)	45.92 (26.44; 47.30)	0.85 (0.00; 1.87)	17.04 (10.72; 29.69)	1.38 (0.25; 2.04)	37.74 (20.00; 43.60)
BR3	1.14 (0.00; 2.21)	41.89 (13.71; 58.90)	1.60 (0.86; 2.55)	58.90 (32.47; 58.90)	0.55 (0.00; 1.60)	18.69 (11.98; 31.75)	1.09 (0.00; 1.74)	45.75 (24.90; 53.58)
BR4	1.44 (0.08; 2.44)	35.76 (12.47; 46.99)	1.88 (1.35; 2.80)	46.15 (27.32; 47.28)	0.79 (0.00; 1.84)	17.69 (11.02; 29.66)	1.35 (0.23; 2.04)	38.55 (20.85; 44.18)
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)	2.02 (1.25; 2.93)	0.00 (0.00; 0.00)	2.73 (2.12; 3.42)	0.00 (0.00; 0.00)
BR0	0.73 (0.00; 2.20)	3.05 (0.99; 5.01)	1.35 (0.46; 2.77)	3.71 (2.42; 5.38)	0.28 (0.00; 1.32)	1.56 (0.90; 2.48)	0.66 (0.02; 1.86)	3.47 (2.42; 5.28)
BR1	1.03 (0.07; 2.36)	2.79 (0.98; 4.42)	1.57 (0.75; 2.96)	3.33 (2.23; 4.66)	0.52 (0.00; 1.60)	1.46 (0.84; 2.32)	0.87 (0.22; 2.01)	3.18 (2.24; 4.62)
BR2	0.95 (0.11; 2.31)	3.21 (1.23; 4.96)	1.43 (0.57; 2.82)	3.89 (2.48; 5.35)	0.53 (0.00; 1.50)	1.92 (0.96; 2.91)	0.85 (0.15; 1.98)	3.67 (2.50; 5.05)
BR3	1.01 (0.07; 2.36)	2.80 (0.98; 4.49)	1.54 (0.72; 2.84)	3.35 (2.28; 4.74)	0.54 (0.00; 1.60)	1.50 (0.86; 2.32)	0.86 (0.21; 1.96)	3.18 (2.27; 4.58)
BR4	1.32 (0.35; 2.64)	2.34 (1.00; 3.89)	1.82 (0.95; 3.17)	2.81 (1.87; 4.12)	0.80 (0.17; 1.81)	1.47 (0.78; 2.07)	1.24 (0.47; 2.24)	2.74 (1.88; 4.01)

Table 4: Stochastic median and 90%iles Br30 and AvC30 values (across the five OMs for each robustness test) for the BR2 CMP. 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.

	Br30		AvC30		5%<0.1	Median <0.2	Median =0
EAST							
WstGw	1.54	(0.71; 1.87)	40.11	(10.70; 46.97)	0	0	0
Qinc	1.01	(0.09; 2.47)	24.45	(11.66; 43.93)	1	0	0
CatOver	1.30	(0.64; 2.05)	26.32	(19.35; 39.56)	0	0	0
HiWmix	0.97	(0.00; 1.86)	45.16	(0.18; 47.59)	2	2	1
BrzCt	0.91	(0.09; 2.48)	25.74	(10.91; 41.72)	1	0	0
TVmix	1.27	(0.45; 2.12)	24.91	(18.16; 36.69)	0	0	0
NLindex	1.63	(0.36; 2.43)	43.05	(12.22; 46.96)	1	0	0
PChgMix	1.33	(0.52; 2.57)	34.45	(13.19; 46.34)	0	0	0
TVregime	1.75	(0.88; 2.56)	37.47	(18.11; 46.57)	0	0	0
IntPar	1.70	(0.68; 2.53)	43.42	(14.58; 46.95)	0	0	0
ZeroEmix	1.29	(0.02; 2.79)	35.68	(13.96; 46.37)	1	0	0
WEST							
WstGw	0.63	(0.00; 1.71)	3.82	(0.91; 5.30)	2	1	0
Qinc	0.36	(0.00; 1.24)	2.35	(0.95; 4.64)	3	1	0
CatOver	0.42	(0.10; 1.16)	3.66	(1.65; 4.60)	1	0	0
HiWmix	1.04	(0.06; 2.51)	3.25	(1.22; 4.36)	1	0	0
BrzCt	0.96	(0.29; 2.28)	2.77	(1.25; 4.35)	0	0	0
TVmix	1.23	(0.50; 2.24)	3.19	(2.15; 4.12)	0	0	0
NLindex	0.87	(0.42; 1.85)	4.09	(1.54; 5.54)	0	0	0
PChgMix	0.53	(0.21; 1.57)	2.77	(1.26; 5.36)	0	0	0
TVregime	0.59	(0.26; 1.40)	4.31	(2.09; 5.61)	0	0	0
IntPar	1.80	(1.12; 3.02)	2.97	(1.74; 4.36)	0	0	0
ZeroEmix	1.39	(0.87; 2.63)	2.70	(1.77; 4.19)	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.

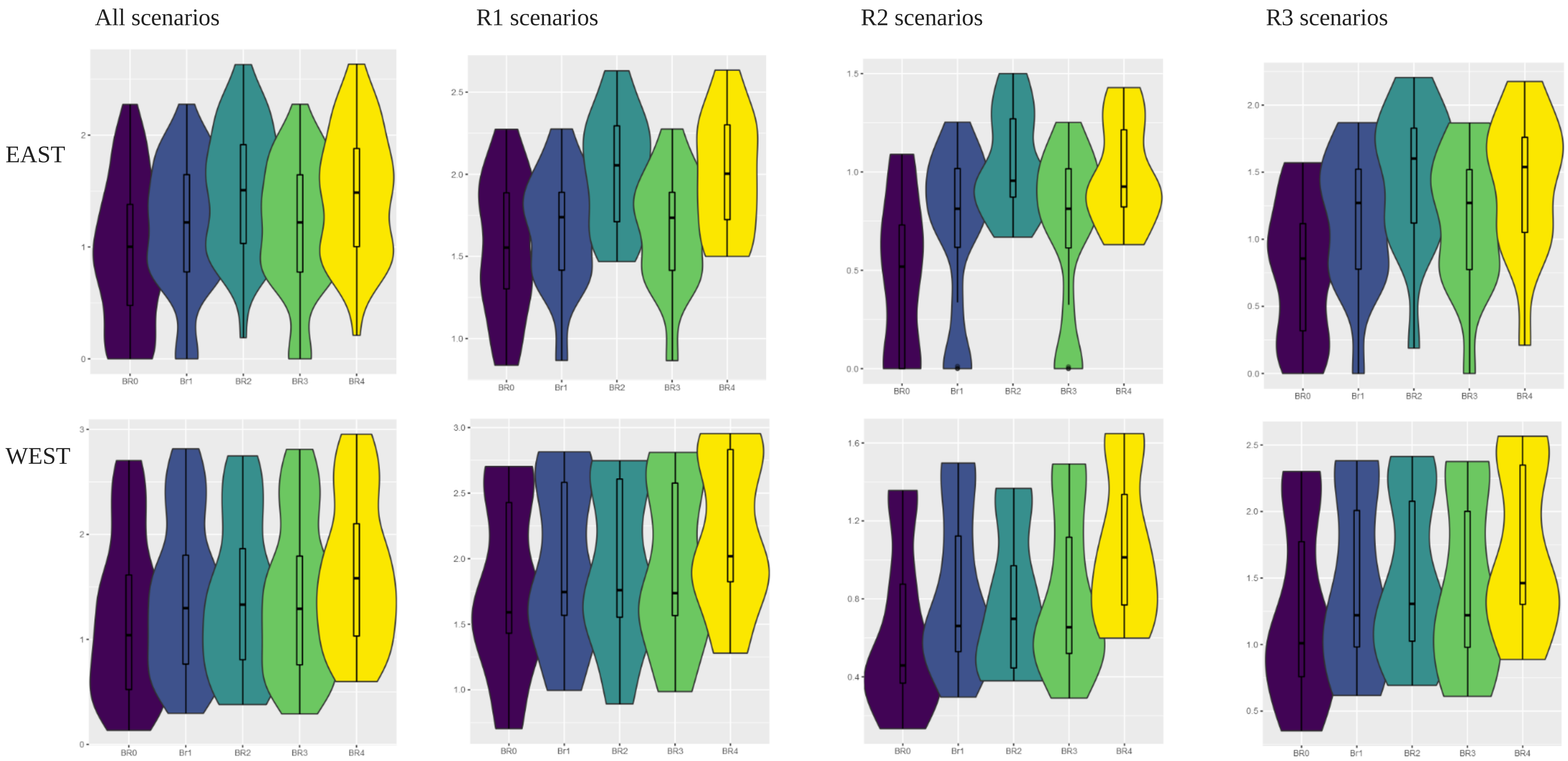

Figure 1a: **Deterministic Br30** values for zero catch and the CMPs considered over the interim grid of OMs for CMPs BR0 to BR4, first for all OMs in the interim grid ("All scenarios"), and then for each of the recruitment scenarios separately, showing median, interquartile and 90%-ile ranges.

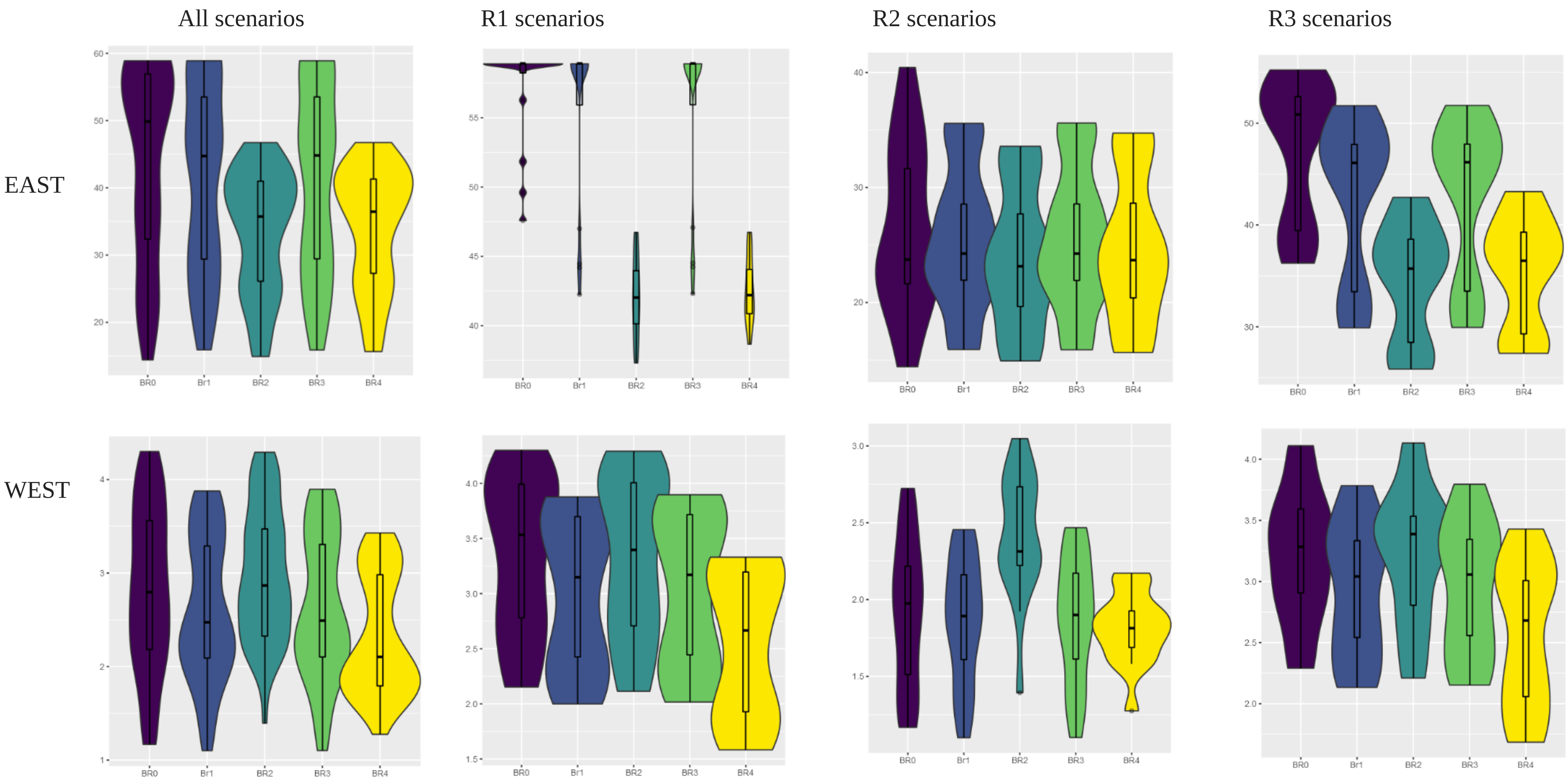

Figure 1b: **Deterministic AvC30** values for zero catch and the CMPs considered over the interim grid of OMs for CMPs BR0 to BR4, first for all OMs in the interim grid (“All scenarios”), and then for each of the recruitment scenarios separately, showing median, interquartile and 90%-ile ranges.

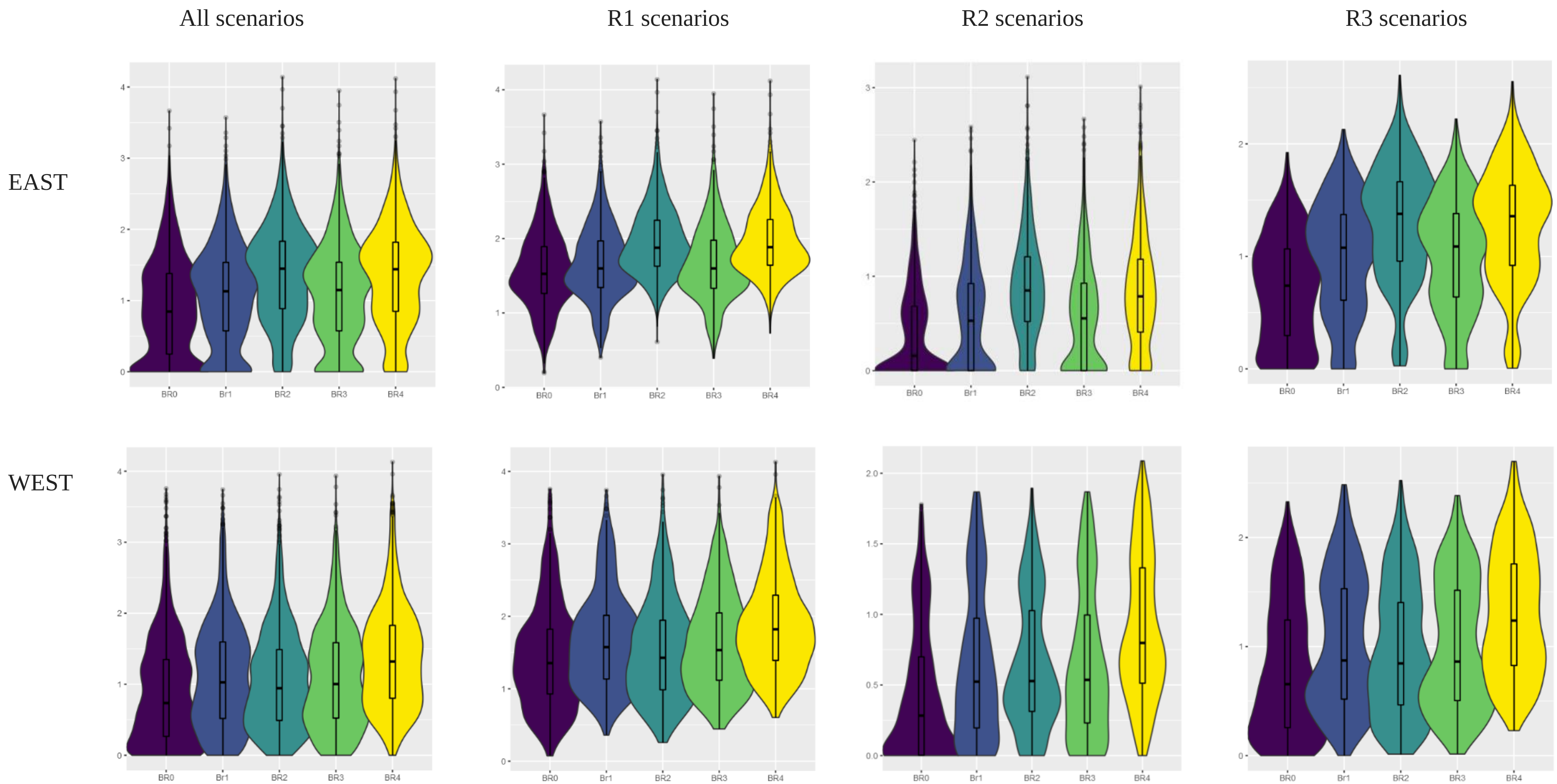

Figure 2a: **Stochastic Br30** values for zero catch and the CMPs considered over the interim grid of OMs for CMPs BR0 to BR4, first for all OMs in the interim grid ("All scenarios"), and then for each of the recruitment scenarios separately, showing median, interquartile and 90%-ile ranges.

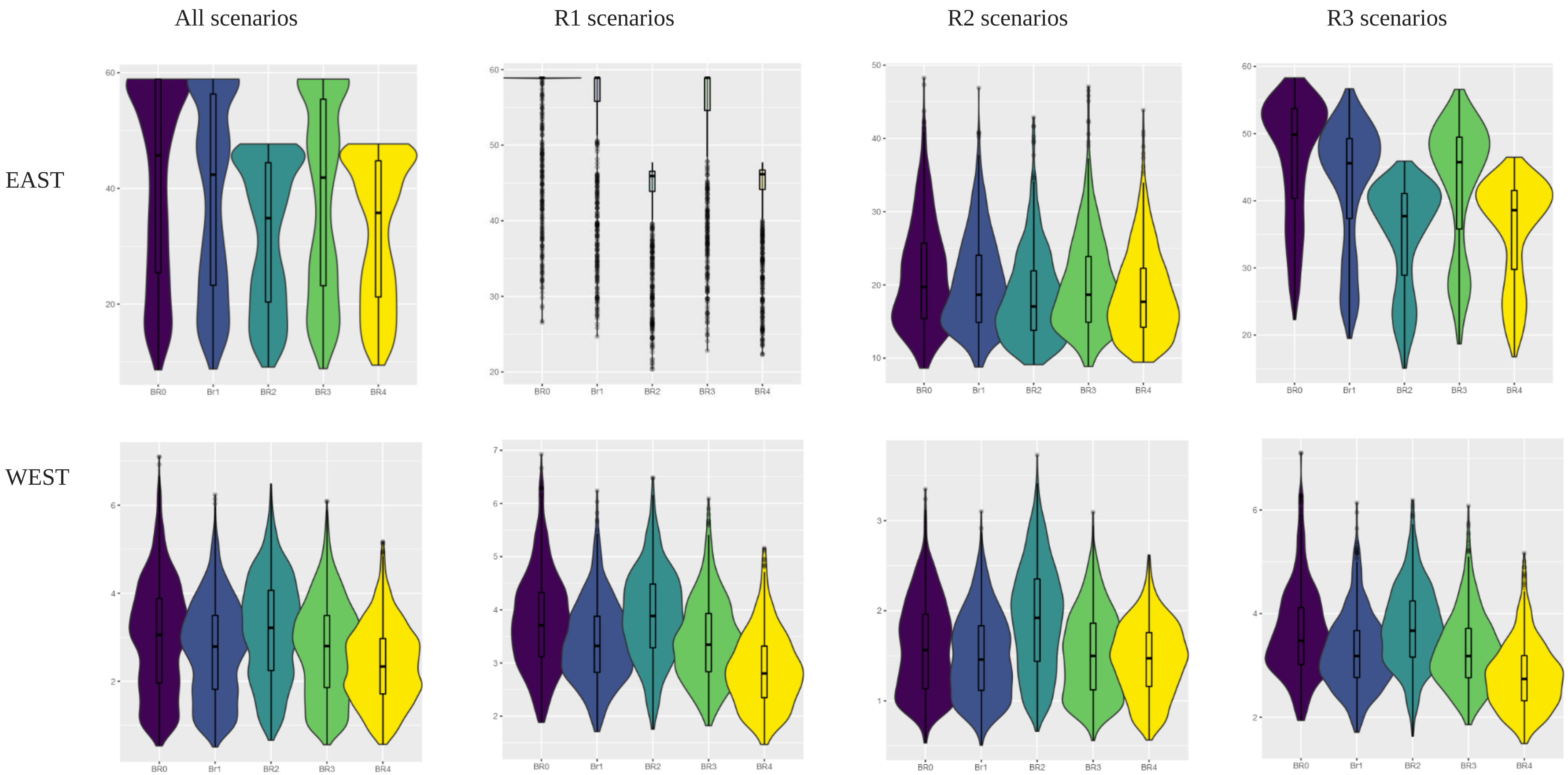

Figure 2b: Stochastic AvC30 values for zero catch and the CMPs considered over the interim grid of OMs for CMPs BR0 to BR4, first for all OMs in the interim grid ("All scenarios"), and then for each of the recruitment scenarios separately, showing median, interquartile and 90%-ile ranges).

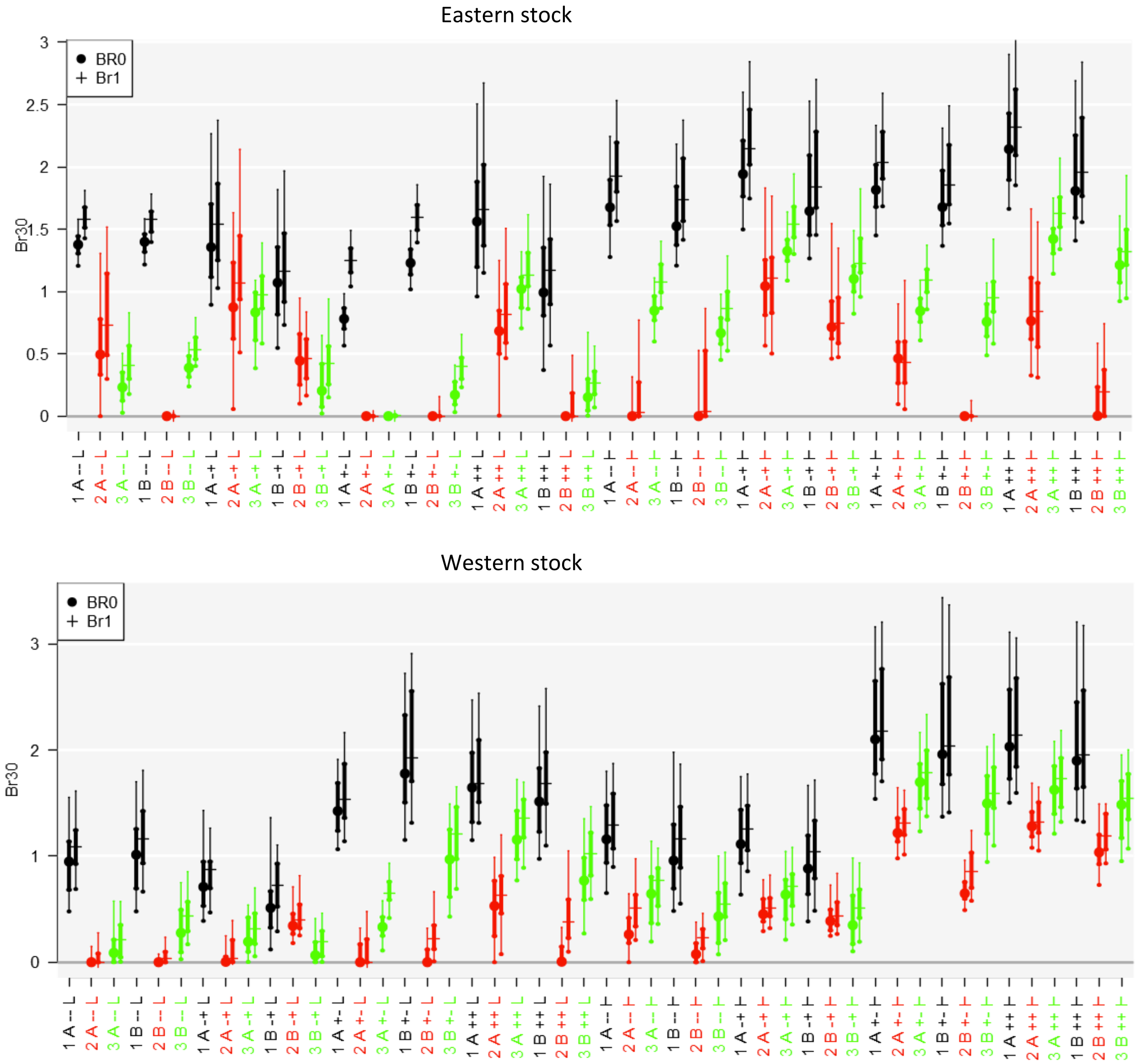

Figure 3a: **Stochastic Br30** results for **BR0** (1.00 East-1.00 West tuning) and **BR1** (1.25 East-1.25 West tuning). The three colours correspond to the three recruitment scenarios: black, red and green to R1, R2 and R3 respectively.

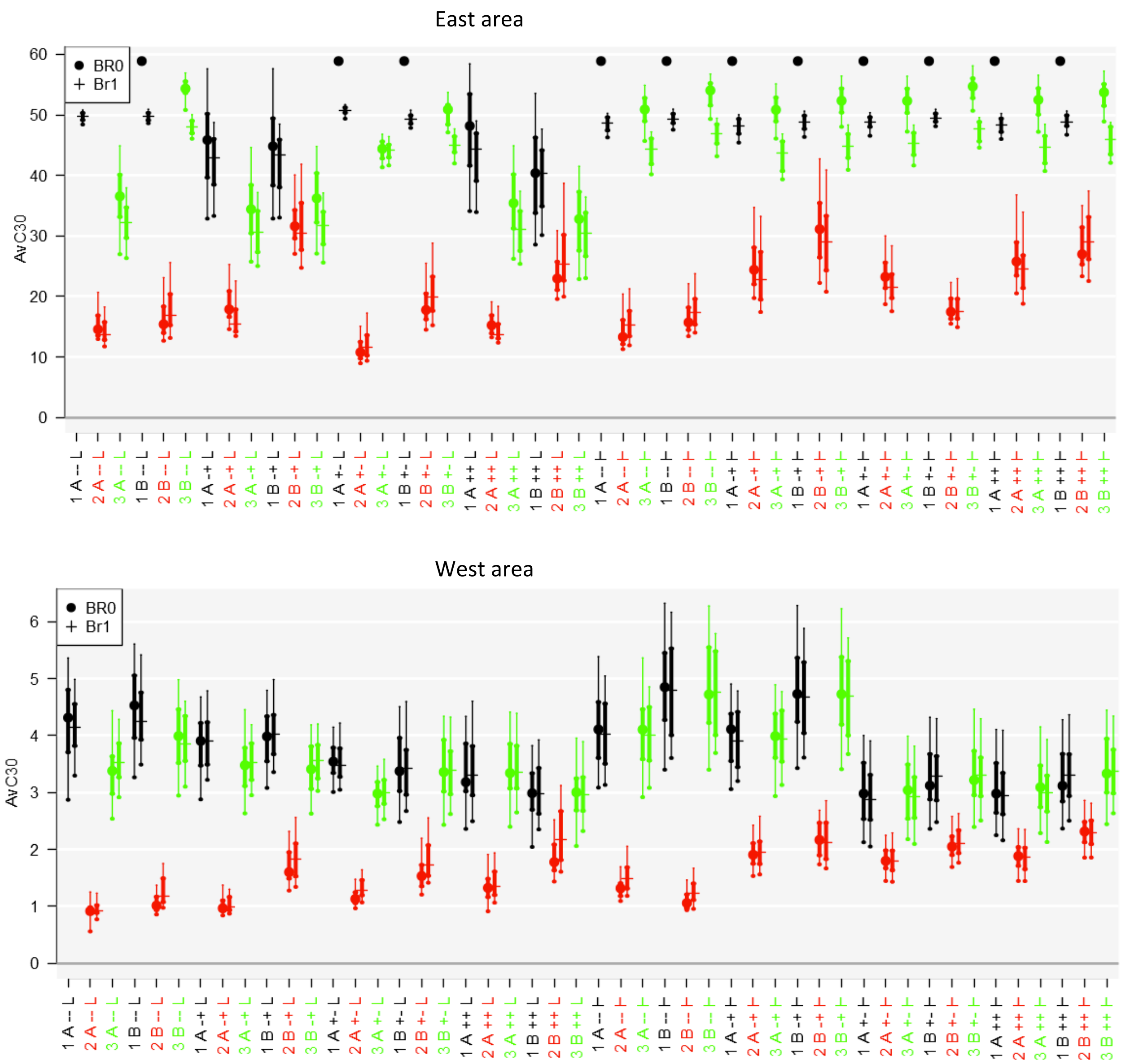

Figure 3b: **Stochastic AvC30** results for **BR0** (1.00 East-1.00 West tuning) and **BR1** (1.25 East-1.25 West tuning). The three colours correspond to the three recruitment scenarios: black, red and green to R1, R2 and R3 respectively.

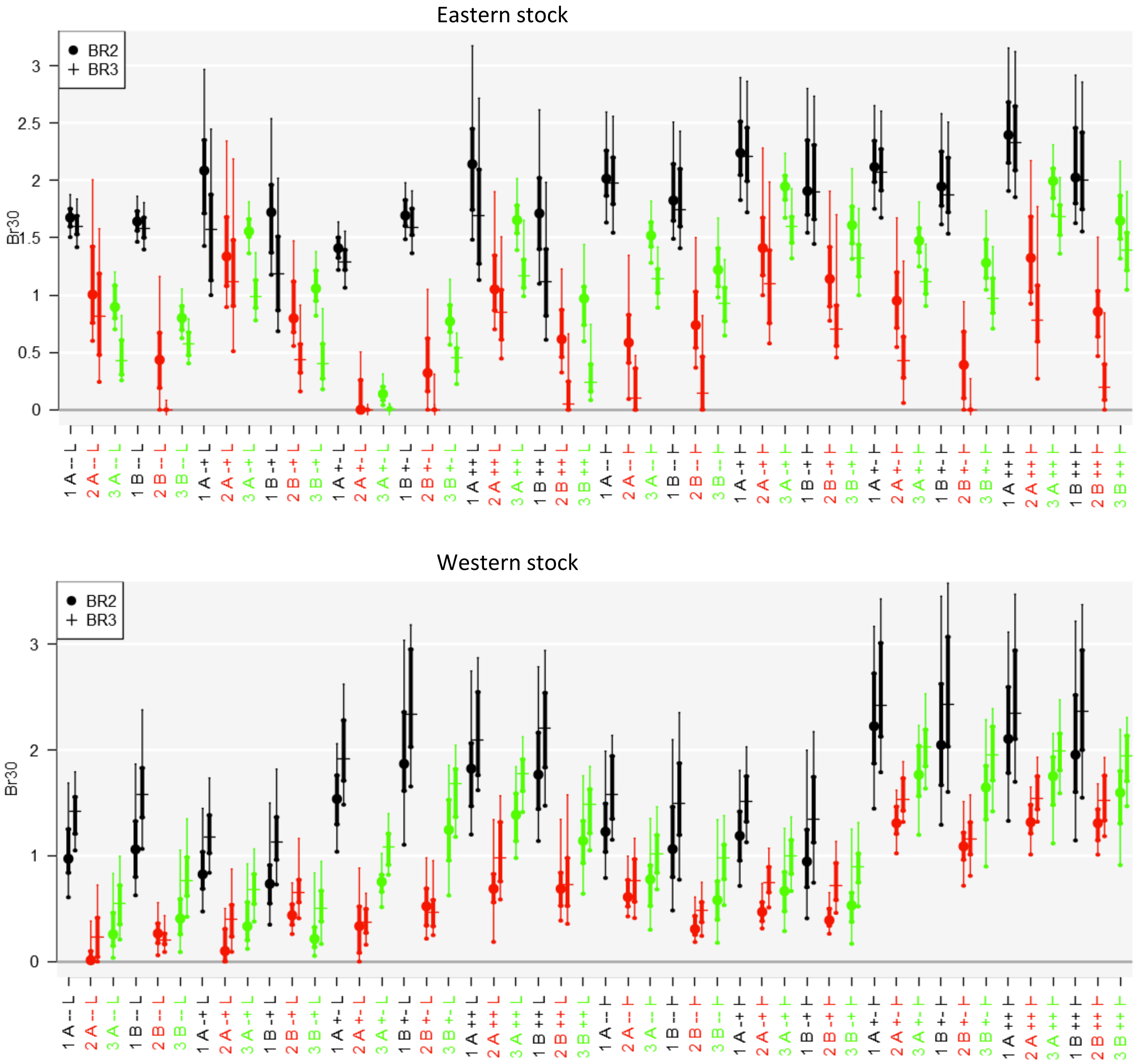

Figure 4a: **Stochastic Br30** results for **BR2** (1.50 East-1.25 West tuning) and **BR3** (1.25 East-1.50 West tuning). The three colours correspond to the three recruitment scenarios: black, red and green to R1, R2 and R3 respectively

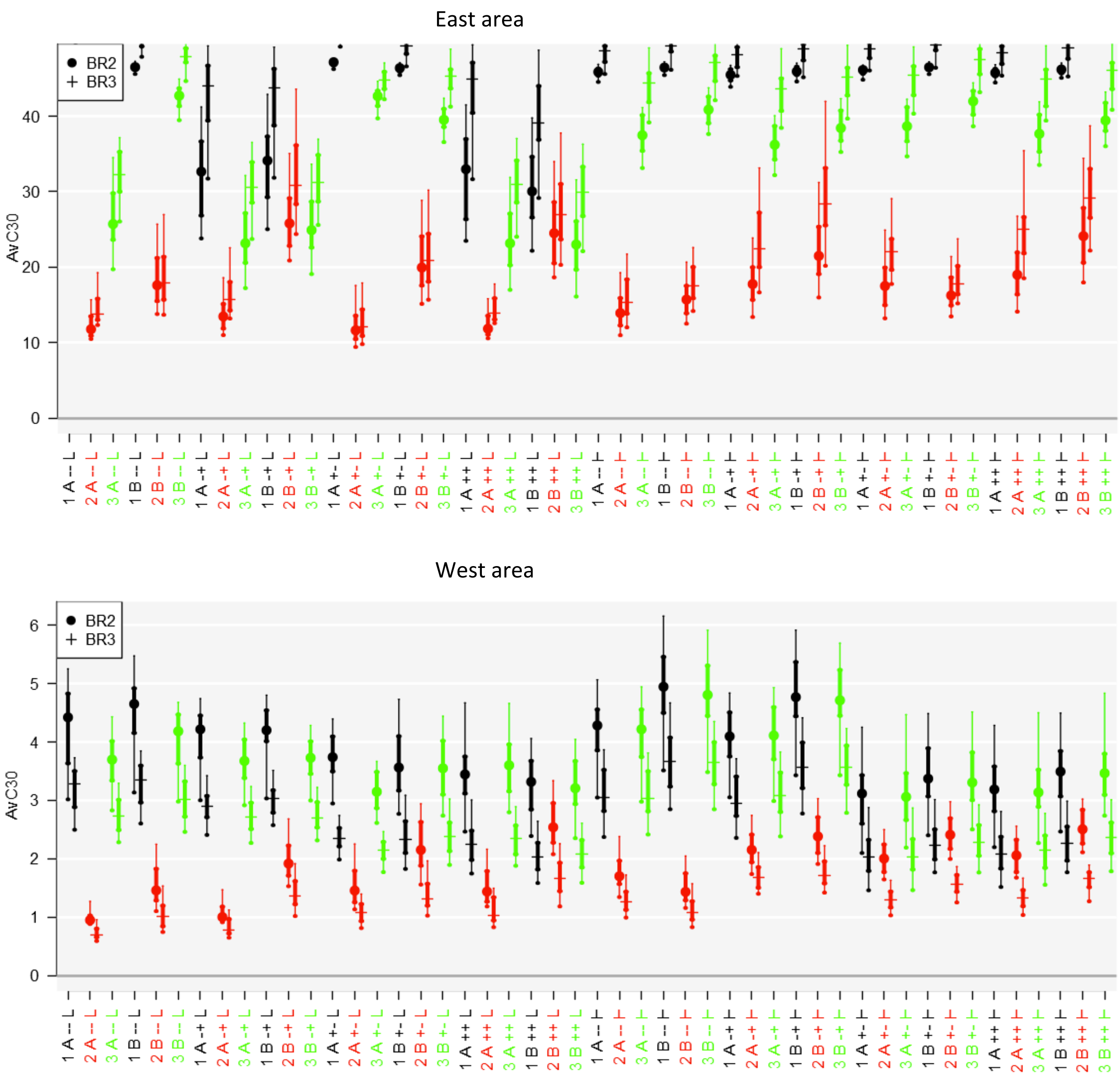

Figure 4b: **Stochastic AvC30** results for **BR2** (1.50 East-1.25 West tuning) and **BR3** (1.25 East-1.50 West tuning). The three colours correspond to the three recruitment scenarios: black, red and green to R1, R2 and R3 respectively

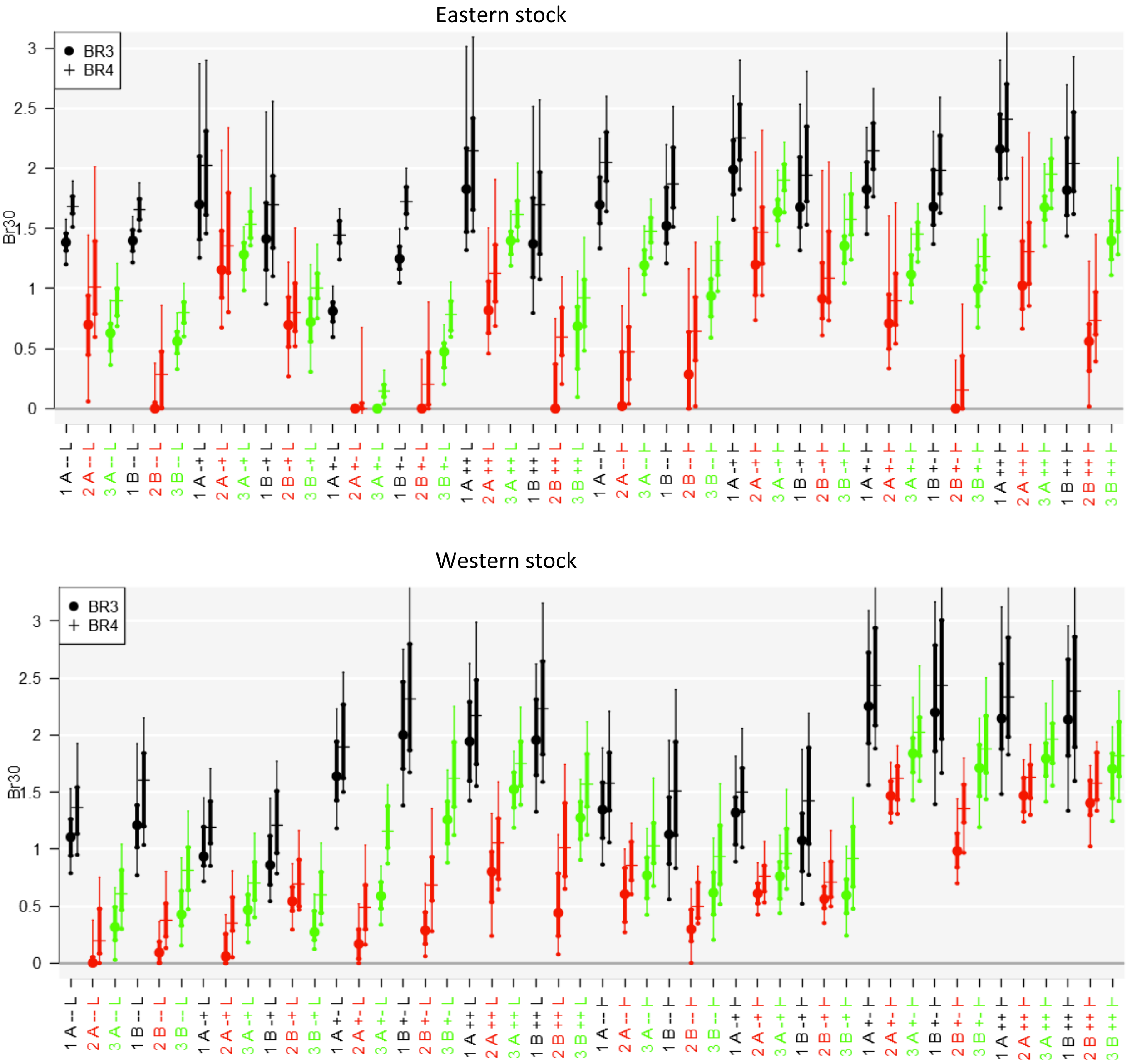

Figure 5a: **Stochastic Br30** results for **BR3** (1.25 East-1.50 West tuning) and **BR4** (1.50 East-1.50 West tuning). The three colours correspond to the three recruitment scenarios: black, red and green to R1, R2 and R3 respectively

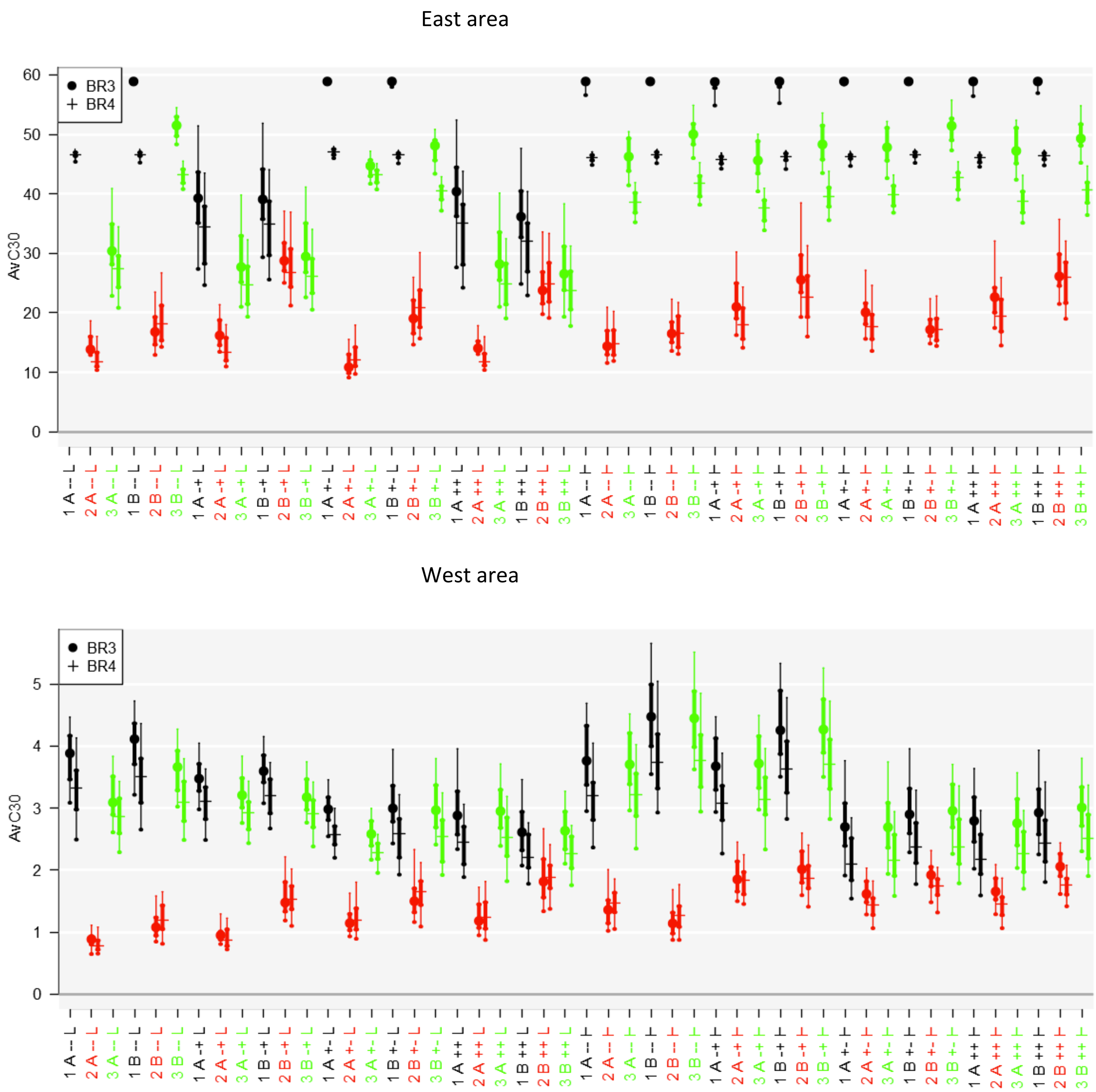

Figure 5b: **Stochastic AvC30** results for **BR3** (1.25 East-1.50West tuning) and **BR4** (1.50 East-1.50 West tuning). The three colours correspond to the three recruitment scenarios: black, red and green to R1, R2 and R3 respectively.

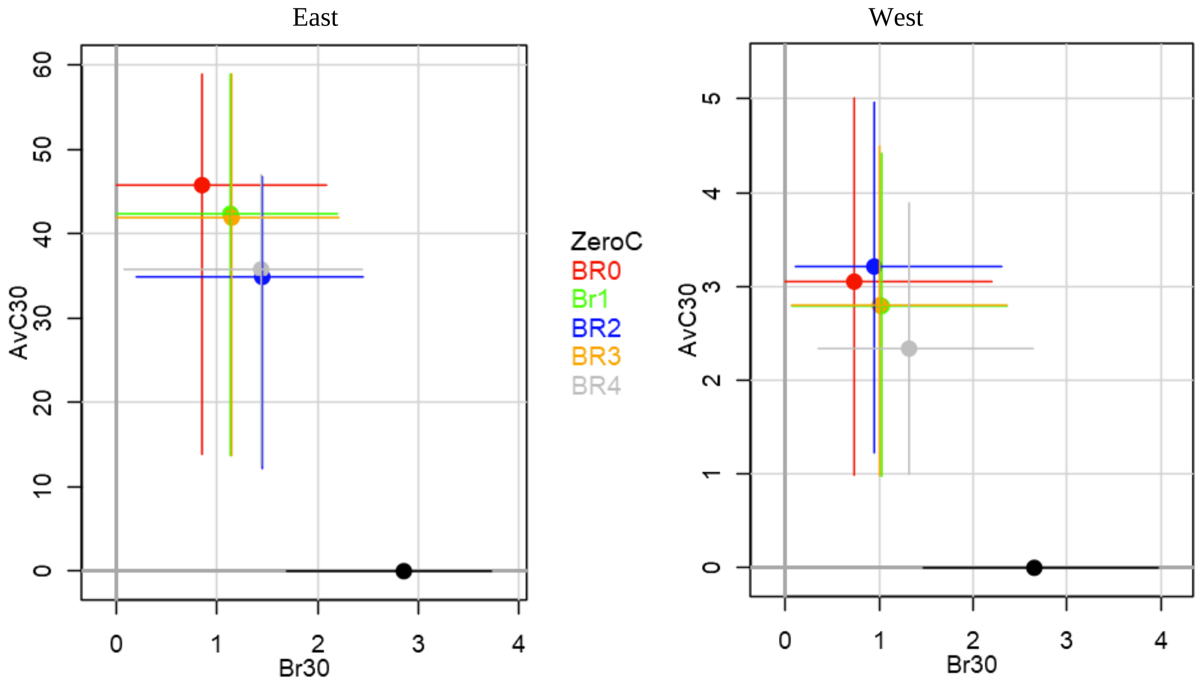

Figure 6: A trade-off plot showing mean and 90%-ile range performance over the interim grid of OMs for stochastic simulations for CMPs BR0 to BR4. Note that in some cases performance is sufficiently similar that the plots for two CMPs show the one set of results overlapping and "hiding" the other.

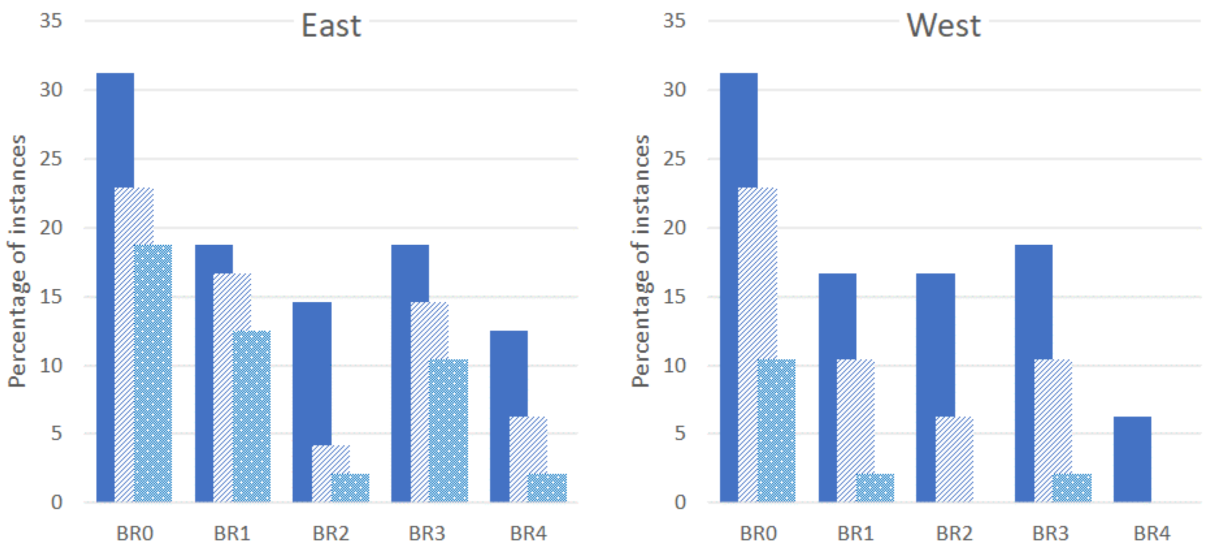

Figure 7a: For each CMP and for the **stochastic** results, the percentage of instances (**all recruitment scenarios, i.e. out of 48 OMs**) is shown that a) the lower 5%ile Br30 falls below 0.1 (full columns), b) the median Br30 falls below 0.2 (diagonal dashed columns) and c) the median Br30 is zero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

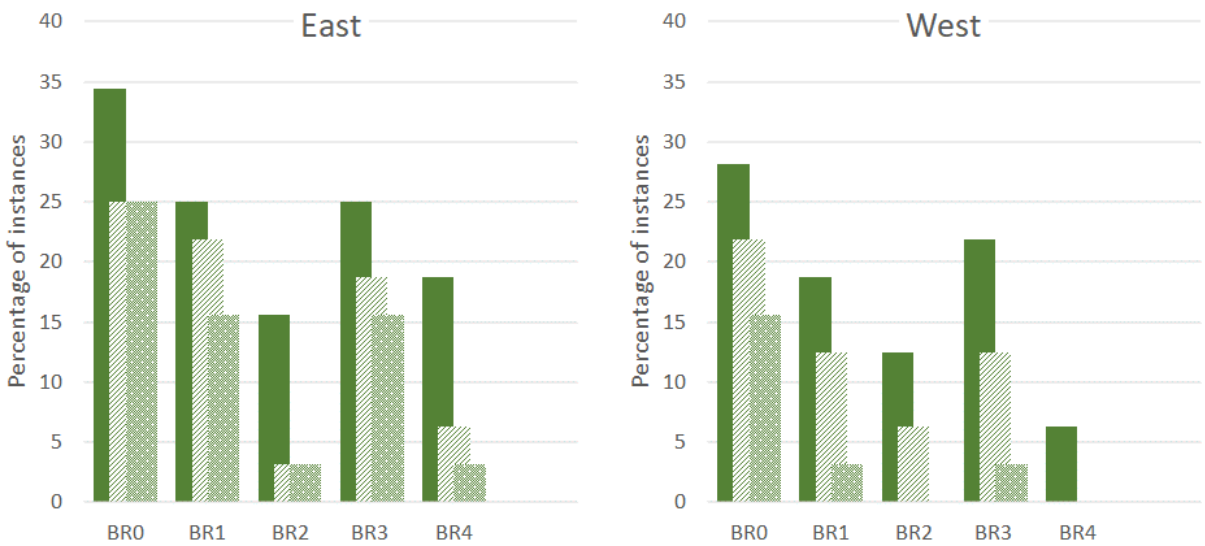

Figure 7b: For each CMP and for the **stochastic** results, the percentage of instances (**recruitment scenarios 1 and 2 only, i.e. out of 32 OMs**) is shown that a) the lower 5%ile Br30 falls below 0.1 (full columns), b) the median Br30 falls below 0.2 (diagonal dashed columns) and c) the median Br30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

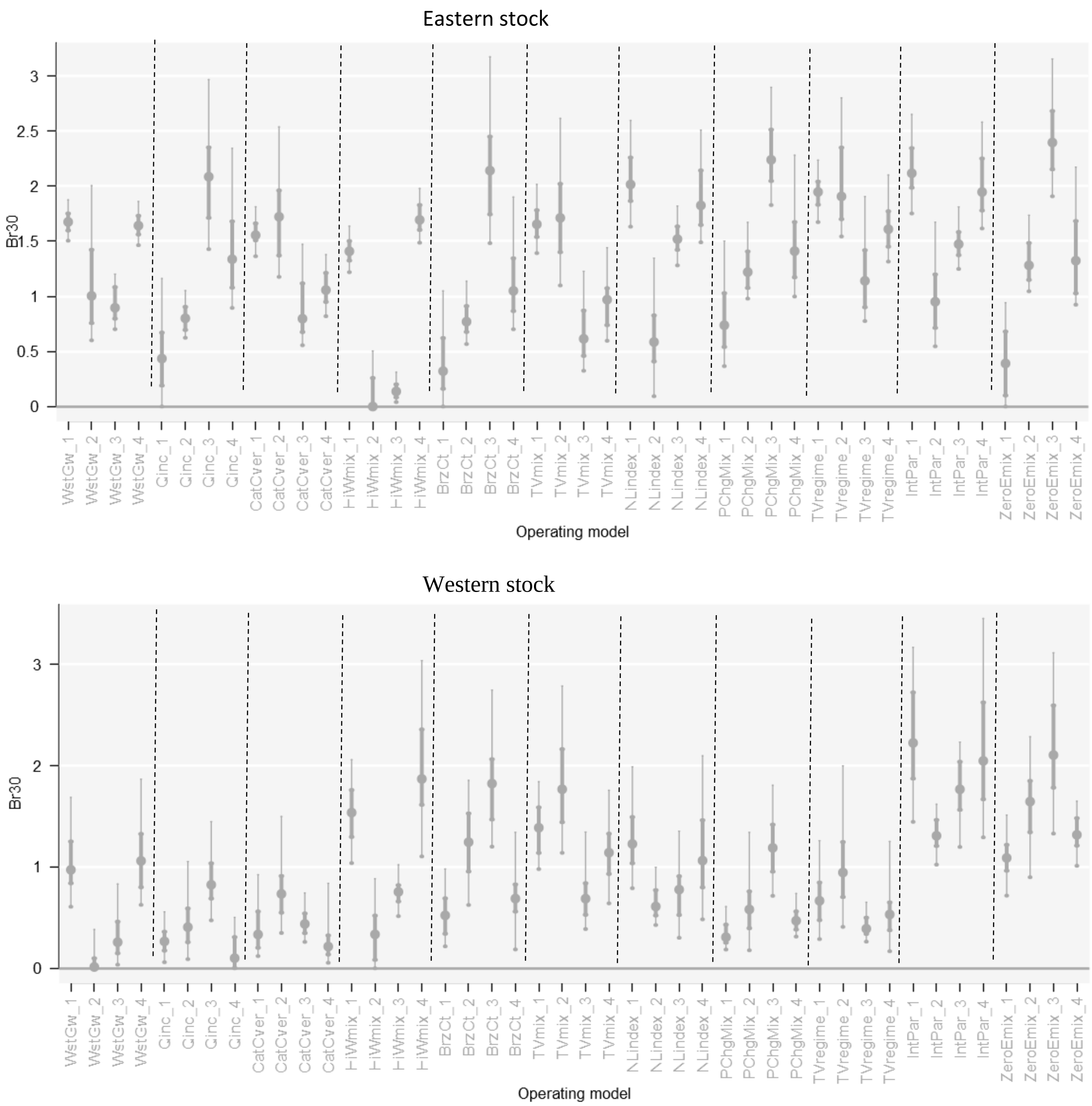

Figure 8a: **Stochastic Br30** results for **BR2** for the robustness tests.

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.

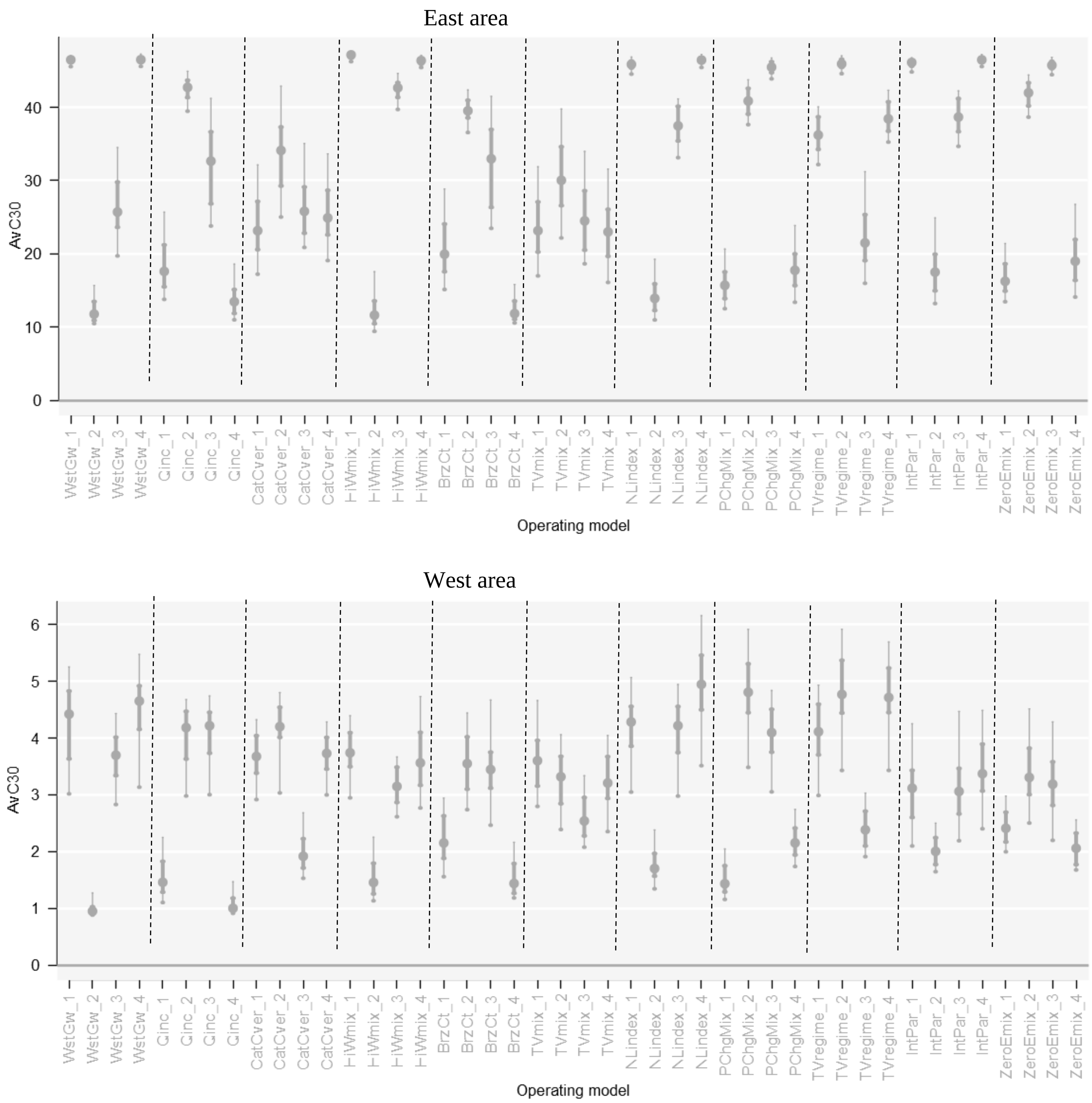

Figure 8b: **Stochastic AvC30** results for **BR2** for the robustness tests.

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.

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.

$J_y^{E/W}$ is an average index over *n* series (*n*=4 for the East area and *n*=6 for the West area)[3]:

$$J_y^{E/W} = \frac{\sum_i^n w_i \times I_y^{i*}}{\sum_i^n w_i} \quad \text{(A1)}$$

where

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

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

$$I_y^{i*} = {I_y^i} \Big/ {Average\ of\ historical\ I_y^i} \quad \text{(A2)}$$

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, $J_{av,y}^{E/W}$, is the average over the last three years for which data would be available at the time the MP would be applied, hence:

$$J_{av,y}^{E/W} = \frac{1}{3}\left(J_y^{E/W} + J_{y-1}^{E/W} + J_{y-2}^{E/W}\right) \quad \text{(A3)}$$

where the $J_{av,y}^{E/W}$ applies either to the East or to the West area.

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[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 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 (note that this section has been changed from earlier versions):

For the West area, the maximum increase is fixed at 20%:

If $TAC_{W,y} \geq 1.2 * TAC_{W,y-1}$ then

$$TAC_{W,y} = 1.2 * TAC_{W,y-1} \qquad \text{(A5a)}$$

For the East area, unless otherwise specified, the maximum increase allowed from one TAC to the next is a function of the immediate past trend in the indices, s^E_y:

$$maxincr = \begin{cases} 0 & s^E_y \leq 0 \\ \text{linear btw 0 and 0.2} & 0 < s^E_y < 0.1 \\ 0.2 & 0.1 \leq s^E_y \end{cases} \qquad \text{(A5b)}$$

where

s^E_y is a measure of the immediate past trend in the average index J^E_y (equation A1), computed by linearly regressing lnJ^E_y *vs* year *y*' for y'=y-6 to y'=y-2 to yield the regression slope s^E_y.

If $TAC_{E,y} \geq (1 + maxincr) * TAC_{E,y-1}$

then $TAC_{E,y} = (1 + maxincr) * TAC_{E,y-1}$ (A5c)

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 for an area 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.

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

$TAC_{W,y} \rightarrow \left[1 + \gamma\left(s_y^W - s^{threshold}\right)\right] TAC_{W,y}$ (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	0.49	GOM_LAR_SUV	1.48
MED_LAR_SUV	0.57	US_RR_66_144	0.57
GBYP_AER_SUV_BAR	0.99	MEXUS_GOM_PLL2	0.88
MOR_POR_TRAP	1.37	JPN_LL_West2	1.09
JPN_LL_NEAtl2	3.49	CAN_SWNS	0.36

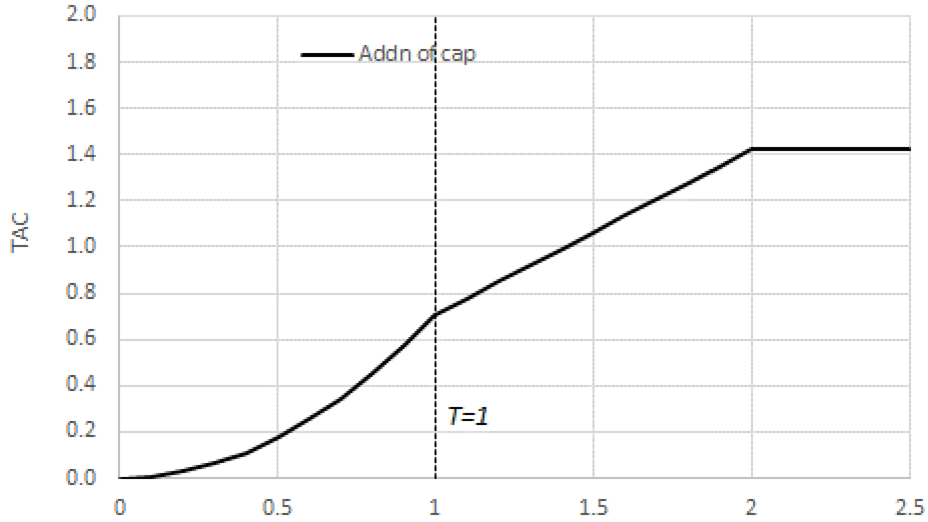

Figure A1. Illustrative relationship (the "catch control law") of *TAC* against $J_{av,y}$ for the BR CMPs, which includes the parabolic decrease below T and the capping of the TAC so as not to exceed some maximum value.