UPDATED CMP RESULTS FOLLOWING SECOND ROUND OF CMP REFINEMENTS

T. R. Carruthers[1]

SUMMARY

MSE performance results for the latest CMPs are presented. These include new AI CMPs and TN CMPs in addition to revised BR and TC CMPs that have borrowed aspects from each other to improve performance. Given comparable eastern Br30 tunings, the TC and BR CMPs have very similar performance. Important trade-offs are apparent among West and East areas and western and eastern stocks. Clearer presentation of East-West trade-offs are required. It may be beneficial to consider additional performance metrics that can account for biomass trends.

RÉSUMÉ

Les résultats des performances de la MSE pour les toutes dernières CMP sont présentés. Il s'agit notamment des nouvelles CMP AI et CMP TN, en plus des CMP BR et TC révisées qui ont emprunté des aspects les unes des autres pour améliorer les performances. Pour des calibrages Br30 Est comparables, les CMP TC et BR ont des performances très similaires. D'importants compromis sont apparents entre les zones Ouest et Est et les stocks Ouest et Est. Une présentation plus claire des compromis Est-Ouest est nécessaire. Il peut être bénéfique d'envisager des mesures de performance supplémentaires qui peuvent tenir compte des tendances de la biomasse.

RESUMEN

Se presentan los resultados del desempeño de la MSE para los últimos CMP. Entre ellos se encuentran los nuevos CMP AI y los CMP TN, además de CMP BR y CMP TC, revisados que han tomado prestados unos aspectos de otros para mejorar el desempeño. Con calibraciones comparables de Br30 oriental, los CMP de TC y BR tienen un desempeño muy similar. Se observan importantes ventajas y desventajas entre las zonas del oeste y del este y los stocks del oeste y del este. Se requiere una presentación más clara de las ventajas y desventajas este-oeste. Puede ser beneficioso considerar mediciones de desempeño adicionales que puedan dar cuenta de las tendencias de la biomasa.

KEYWORDS

Management Strategy Evaluation, bluefin tuna, operating model, management procedure

[1] Blue Matter Science Ltd., 2150 Bridgman Ave, North Vancouver, BC. V7P 2T9. tom@bluematterscience.com

Introduction

In December 2020, MSE performance results for 28 CMPs were presented. These CMPs had tuning parameters that allow the MPs to achieve comparable biological performance. By controlling for a major axis in performance outcomes, this development tuning allows for clearer comparison among other performance metrics. For the purposes of development tuning, biological performance is characterized by spawning biomass relative to dynamic spawning stock biomass at MSY after thirty years (Br30). CMPs are tuned to Br30 levels of 1.00, 1.25 and 1.5 for the western stock only. Developers were not provided with instructions for tuning to eastern stock performance outcomes.

Subsequently, BR and TC developer teams have undertaken two rounds of CMP refinement that were intended to reduce the variability in performance outcomes for a given CMP tuning. In the first set of refinements both BR and TC CMPs borrowed aspects from each other to improve performance. A revised TC CMP (TC5) made use of CPUE indices in the West that were indicative of younger fish and hence were expected to be more responsive to recruitment changes in that stock. The revised BR CMP (BR6) was adapted to account for the slope in western stock indices. When western stock declines are simulated, slope is expected to change faster than absolute index level, improving the responsiveness of the CMP.

The first refinements were presented in January 2021 where it was clear that the new BR6 CMP had shown substantial performance gains over the previous version (BR0). By comparison, the TC5 performance gains were lesser and only apparent for a small number of operating models for which western biomass outcomes were particularly low. Given the now favourable performance of the BR6 CMP, a number of potential improvements to the TC5 CMP were proposed that mimicked aspects of the BR6 CMP. Those refinements are described in more detail in the Methods below, including a brief description of the latest refinements to the BR CMP.

It was observed recently (N. Duprey comm.) that the existing CMPs - that are still in development - do not appear to be as responsive as they could be, substantially underfishing for some OMs and overfishing in others. Artificial neural networks were investigated as a basis for learning about possible improvements to CMP algorithms (SCRS/2020/028). Although first intended as an exploratory tool, when used directly to provide advice these neural networks provided favourable yield and biological performance. These artificial intelligence (AI) CMPs were tuned to comparable levels of western and eastern Br30 as the TC and BR CMPs and are included in this CMP comparison.

The latest CMP results are presented here focusing predominantly on the western Br30 = 1.00 development tuning since that includes the largest number of CMPs.

Methods

Latest refinements to the TC CMPs (TC4, TC5, TC6 to TC10, TC11, TC12)

Previously refined TC CMPs were tuned to western stock Br30 1.00, 1.25 and 1.50 (TC4, TC5 and TC6, respectively). The CMP was updated with the following changes to better correspond with the BR6 CMP that obtained favourable performance outcomes:

1. Adjustment of West area TACs using slope in the US_66_114 CPUE index that may be more responsive to recruitment changes than the Gulf of Mexico Larval Survey (GOM_LAR_SUV);
2. Removal of a short-term cap on West area TACs for the first 15 years of CMP use that could be deemed omniscient as it is appropriate only to the specific recruitment shift of the recruitment level 3 scenario;
3. Increase in the overall West area TAC cap to improve yield performance;
4. Reduction in the overall East area TAC cap to improve biological performance in the West;
5. Increase in the allowable maximum TAC reduction to 35% to allow for more responsive TAC reductions given recruitment level 2 scenarios.

Given these changes, the CMP was re-tuned to median western stock Br30 of 1.00, 1.25 and 1.50 (TC10, TC11 and TC12, respectively).

Latest refinements to the BR CMPs (BR7 to BR10, BR11, BR12)

Greater detail of the changes to the BR CMP is provided in SCRS/2021/042 (Butterworth and Rademeyer 2021). The principal changes were a reduction in the maximum downward adjustment to the TAC for both areas, from 50% to 30% and a temporary 10-year cap on East TAC of 36kt. Three BR CMPs are presented here that are a further refinement of the BR7 CMP but tuned to the three prescribed levels of western Br30.

CMPs presented

A brief description of the design and tunings of CMPs with current developer support is presented in **Table 1**.

Results

The biomass (Br30), yield (AvC30) and variability in yield (AAVC) performance of all CMPs is presented in **Table 2.**

For those CMPs tuned to western stock Br30 = 1.00, there were differences in the range of western Br30 outcomes, with the AI1 CMP providing the tightest distribution, followed by the BR10 and TC10 CMPs that provided somewhat tighter ranges than the remaining CMPs (**Figure 1**). AI1, BR10 and TC10 CMPs were tuned to comparable median Easter Br30 levels of approximately 1.60, however other CMPs were generally tuned lower to a value of around 1.00 (this eastern development tuning was left to the discretion of the developers and not specified). These various tunings revealed the expected negative trade-off between East yield and eastern biomass outcomes (**Figure 5**).

Despite sharing the same western Br30 tuning, West area yield (AvC30) varied substantially in both variance, shape of distribution (i.e. unimodal vs bimodal) and median level among the CMPs. The AI1, BR10 and TC10 CMPs provided the highest median yields (**Table 1, Figure 1**). The AI1 and LW1 CMPs showed pronounced yield bimodality across the OMs. In the case of the AI1 CMP, this can be attributed to tailoring catches better to the vulnerable biomass that varies strongly across recruitment scenarios (**Figures 10a and 10b**) which is the key determinant of its tighter western and eastern Br30 distributions.

In general, among CMPs there was a positive correlation between eastern stock Br30 and West area yields (AvC30), and a negative relationship between East area AvC30 and West area AvC30 (**Figure 4**). The slope of the negative trade-off in AvC30 among CMPs was approximately -1:16, costing 1kt in the West for every 16kt gained in the East area. Care should be taken in the interpretation of this result. In general, eastern Br30 and East area AvC30 outcomes are not responsive to catch levels in the West area because the eastern stock is so much larger than the western stock. The correlation is an emergent pattern among CMPs *post tuning*: it is simply the case that once an eastern Br30 tuning is specified, it strongly determines what is achievable in the West area. Therefore, even though the -1:16 correlation among tuned CMPs is apparent, the causation runs almost entirely East to West. Accordingly for any given CMP, increasing West area catches will not cause any meaningful change in eastern stock and East area outcomes.

Median yield and biomass trajectories for the CMPs (**Figure 6a**) showed varying trends which are not well characterized by the Br30 and AvC30 metrics. CMPs tuned to lower eastern stock Br30s appeared more likely to have declining biomass trends through that projection year (**Figure 6a**). Despite the same western Br30 tuning, there were various biomass trends among CMPs through projection year 30. In general, the median yield and biomass outcomes (**Figure 6a**) were more similar than the same quantities projected at their 10^{th} percentiles (**Figure 6b**), for which certain aspects of CMP behaviour were more apparent such as possible extirpation (e.g. EA7 and EA8).

A side-by-side comparison of the CMPs with the best West area yield given a western Br30=1.00 tuning (AI1, BR10, TC10) (**Figure 7**) reveals that the AI1 CMP provides quite different performance outcomes compared with the more conventional index-based rules of BR10 and TC10 (even though TC10 is unlike BR10 in that it attempts to account for stock mixing by using indices from the opposing side of the Atlantic). The AI1 CMP has much lower variability in yields among the 2-year TAC setting interval (AAVC), a strongly bimodal AvC30 yield outcome for both East and West areas and tighter Br30 distribution for both eastern and western stocks.

After several rounds of refinement, the TC10 and BR10 CMPs provide very similar Br30 performance across the various individual operating models (**Figure 8**).

Projection plots of outcomes among the interim grid of operating models reveal varying behaviour among the best performing CMPs. For example, the TAC caps in the East and West area become apparent (**Figure 9**). When these results are disaggregated by operating model recruitment level, interesting differences among the CMPs become apparent (**Figures 10a-c**). For example, the AI1 CMP can throttle catches in the East very quickly given recruitment level 2, for which TC10 and BR7 CMPs require several years to detect and respond to the much lower initial recruitment in these scenarios (**Figure 9b**). The AI1 CMP appears too conservative in recruitment level 2 OMs and tends to chronically underfish (**Figure 10b**). Furthermore, the AI1 CMP is more biologically risky than the BR10 and TC10 CMPs for some recruitment level 3 operating models, where it shows continued declines in more distant projection years (**Figure 10c**).

In general, the patterns in performance observed for the western Br30 = 1.00 development tunings were also evident among CMPs tuned to western Br30 = 1.25 (**Figures 11a-c**).

Discussion

Recent refinements to the BR and TC CMPs have provided gains in performance by borrowing various aspects including the input data used and the form and parametrization of the CMP algorithms. These two classes of CMP now performance very similarly.

It is increasingly apparent that trade-offs exist among East and West areas and eastern and western stocks. The presentation of MSE results should illustrate these more clearly, for example, in the online Shiny app.

Biomass projection plots reveal the potential benefits of considering additional metrics that account for biomass trend. For example, comparable Br30 metrics could be obtained from CMPs with declining or increasing trend in biomass. Biomass trend could provide useful additional information for choosing between CMPs that are otherwise similar in performance.

Although they are based on very different assumptions and technology than the conventional index-based CMPs such as BR and TC, the AI MPs show promising performance and should be subject to further investigation and refinement. When considering the use of more complex CMPs such as those based on artificial neural networks that have been trained on projected data, there is greater need for consideration of CMP overparameterization omniscience and ultimately, robustness. A discussion of these issues is included in paper describing the AI CMP formulation and training (SCRS/2020/028).

Acknowledgments

Many thanks to Doug Butterworth for his comments on an earlier draft. This work was carried out under the provision of the ICCAT Atlantic Wide Research Programme for Bluefin Tuna (GBYP), funded by the European Union, several ICCAT CPCs, the ICCAT Secretariat and by other entities (see: http://www.iccat.int/GBYP/en/Budget.htm). The contents of this paper do not necessarily reflect the point of view of ICCAT or other funders and in no ways anticipate ICCAT future policy in this area.

Table 1. The CMPs that currently have developer support, for which results are presented in this paper.

CMP	Developer	Description	West stock Br30 tuning
AI1 +	Tom Carruthers (Blue Matter)	TAC recommendations come from a fixed harvest rate applied to area biomass estimated by an artificial neural network (SCRS/2020/028).	1.03
AI2 +			1.26
AI3 +			1.51
BR10 **	Doug Butterworth, Rebecca Rademeyer (MARAM)	TACs proportional to average over abundance index values (SCRS/2020/147 & SCRS/2020/160).	1.00
BR11 **		Adds: Index trend value also used for west area TAC.	1.25
BR12 **		Adds: East area TAC not to increase for next 10 years.	1.50
EA7 *	Eider Andonegi (AZTI)	Uses weighted mean. Tuned to East Br30 = 1.	1.00
EA8 *		Uses weighted median, Tuned to East Br30 = 1.	1.00
LW1	Matt Lauretta, John Walter (NOAA)	Index based MP uses MED_LAR_SUV in the East and GOM_LAR_SUV in the West. Refinements of LW1 & 4 above. Adds: max catch in E, max allowable TAC change, years over which to estimate moving average for index, and inclusion of a minimum western index threshold which would trigger an emergency western catch=0.	1.01
LW4			0.84
LW5 *			0.96
LW6 *			0.99
TC10 **	Tom Carruthers (Blue Matter)	MPx CMP assuming stock mixing, using US_RR_66_114 and US_RR_115_144 CPUE indices (SCRS/2020/165), in these iterations these add the US_RR_66_114 for slope, max TAC change down is 35%, max East TAC is 45kt, max WTAC is 3kt, WTAC is max 2.5kt for first 4 years.	1..00
TC11 **			1.26
TC12 **			1.50
TN1	Yohei Tsukahara and Shuya Nakatsuka (AFFRC)	CPUE based CMP is a CMP developed by JPN team. This CMP is very simple and works with 3 CPUE time series (SCRS/2020/151 & SCRS/2020/166).	1.00
TN2 +			1.25
TN3 +			1.50

** new and a refinement following Dec 2020 meeting*
*** new and a further refinement following February 2021 meeting*
+ CMP is new

Table 2. Median performance of the latest CMPs for all reference set operating models combined. AvC30 is the average yield over the first 30 years that the CMP is in use (2022 – 2051), AAVC is the average annual variability in catches and Br30 is spawning stock biomass relative to dyamic spawning stock biomass at MSY.

	West area / western stock			East area / eastern stock		
CMP	**AvC30**	**AAVC**	**Br30**	**AvC30**	**AAVC**	**Br30**
ZeroC	0.00	0.00	2.78	0.00	0.00	3.41
Br30 = 1.00 tunings						
EA7 *	1.70	6.91	1.00	45.81	8.40	1.01
EA8 *	1.69	7.20	1.00	44.84	8.47	1.01
LW1	1.89	9.13	1.01	43.29	11.14	0.99
LW5 *	1.77	13.04	0.96	44.84	0.00	1.08
LW6 *	1.68	9.12	0.99	44.84	0.00	1.07
TN1	1.72	5.70	1.00	41.08	8.94	1.21
BR10 **	2.11	4.67	1.00	36.44	0.00	1.55
TC10 **	2.24	0.00	1.00	38.17	0.00	1.54
AI1 +	2.40	0.00	1.03	40.37	0.00	1.58
Br30=1.25 tunings						
TN2 +	1.46	5.26	1.25	30.58	9.38	1.85
BR11	1.63	3.99	1.25	36.53	0.00	1.56
TC11 **	1.62	5.03	1.26	38.15	0.00	1.56
AI2 +	1.78	0.00	1.26	40.53	0.00	1.60
Br30=1.50 tunings						
TN3 +	1.41	5.03	1.50	22.59	5.05	2.20
BR12	1.04	6.29	1.50	36.64	0.00	1.57
TC12 **	1.01	5.52	1.50	38.13	2.52	1.58
AI3 +	1.28	0.00	1.51	40.55	0.00	1.60

** new and a refinement following Dec 2020 meeting*

*** new and a further refinement following February 2021 meeting*

+ CMP is new

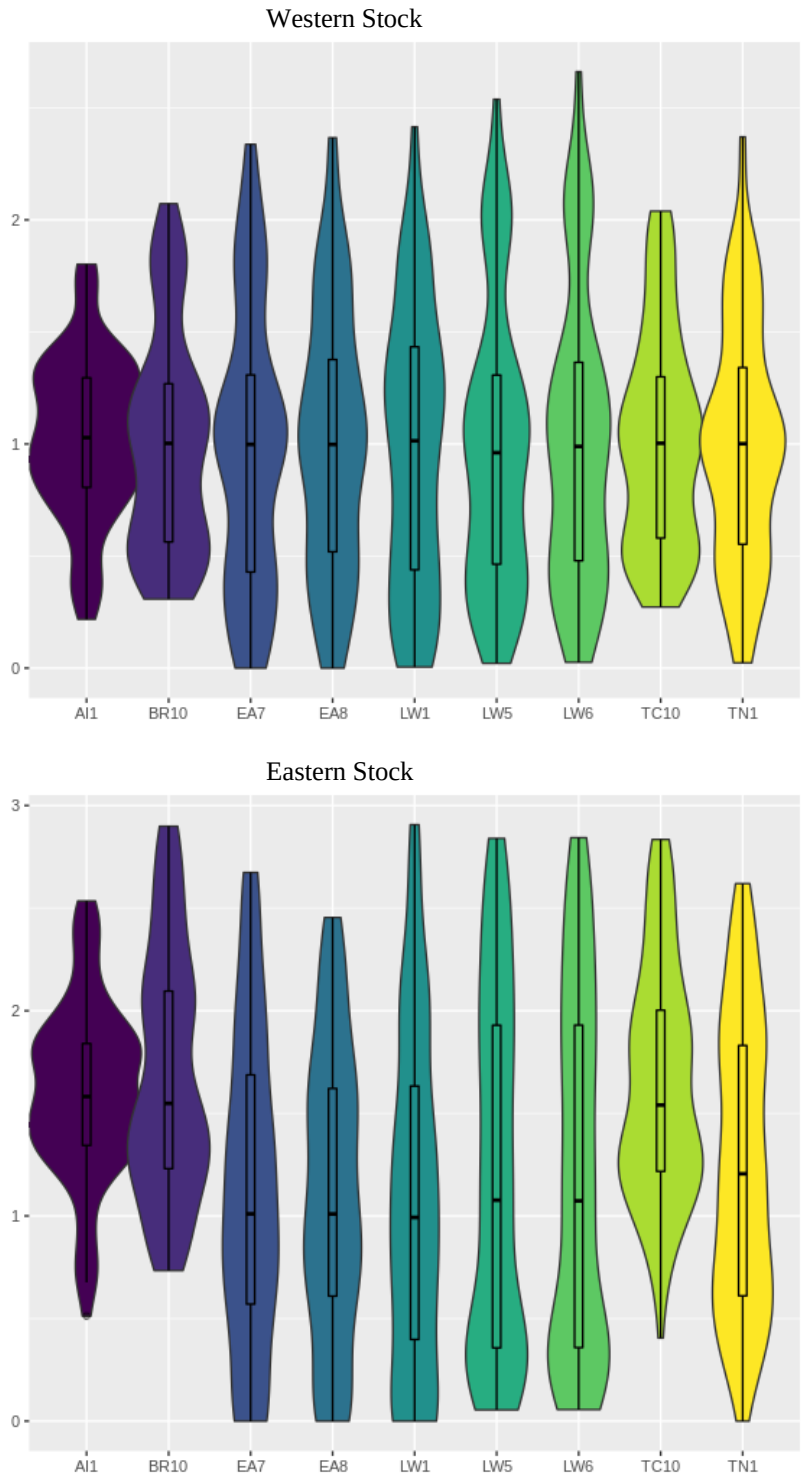


Figure 1. Biological performance (Br30) of CMPs tuned to western stock Br30 = 1. Box plots show median, interquartile range (box) and 95% interquantile range.

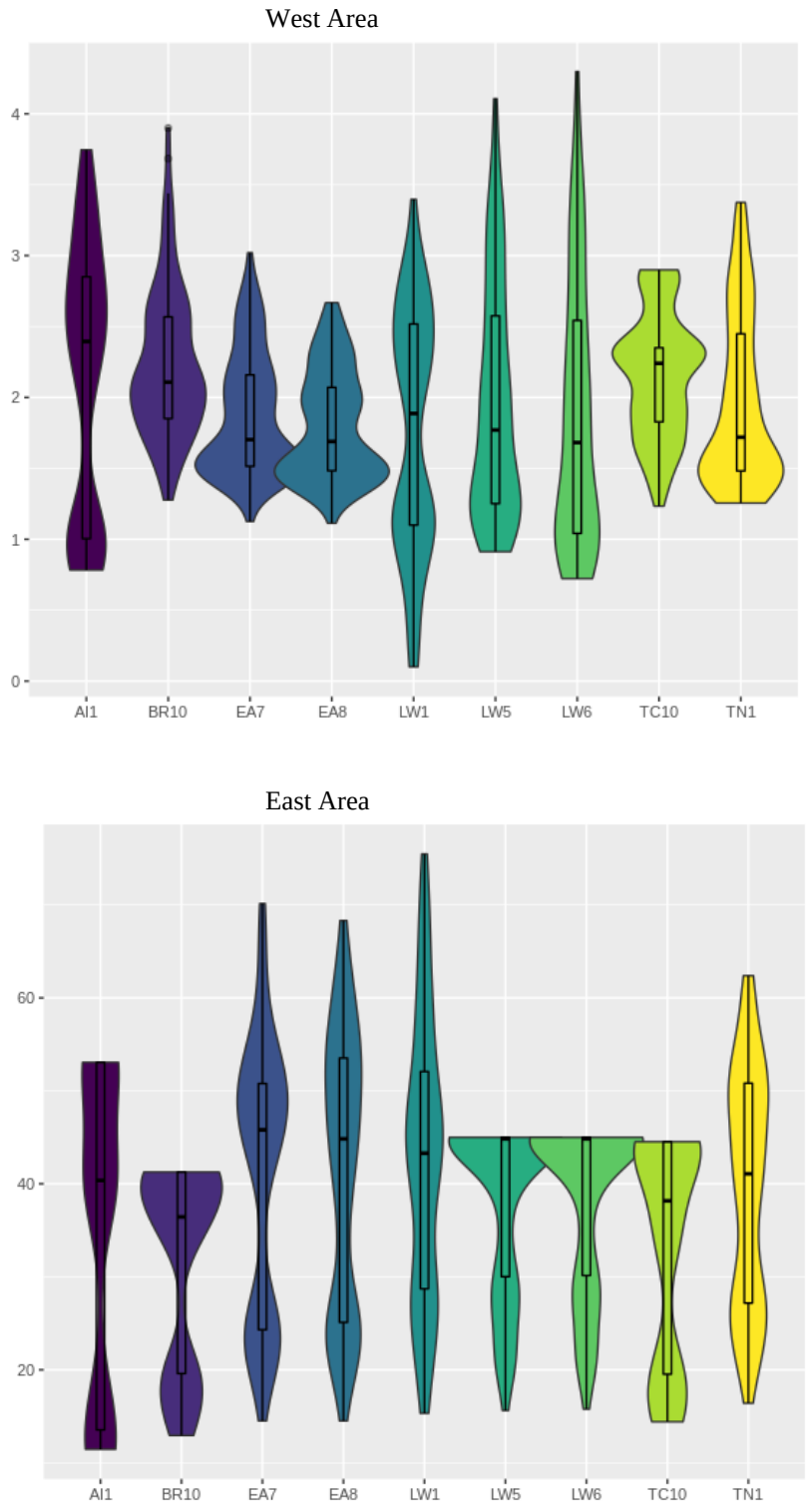


Figure 2. Yield performance (AvC30) of CMPs tuned to western stock Br30 = 1.

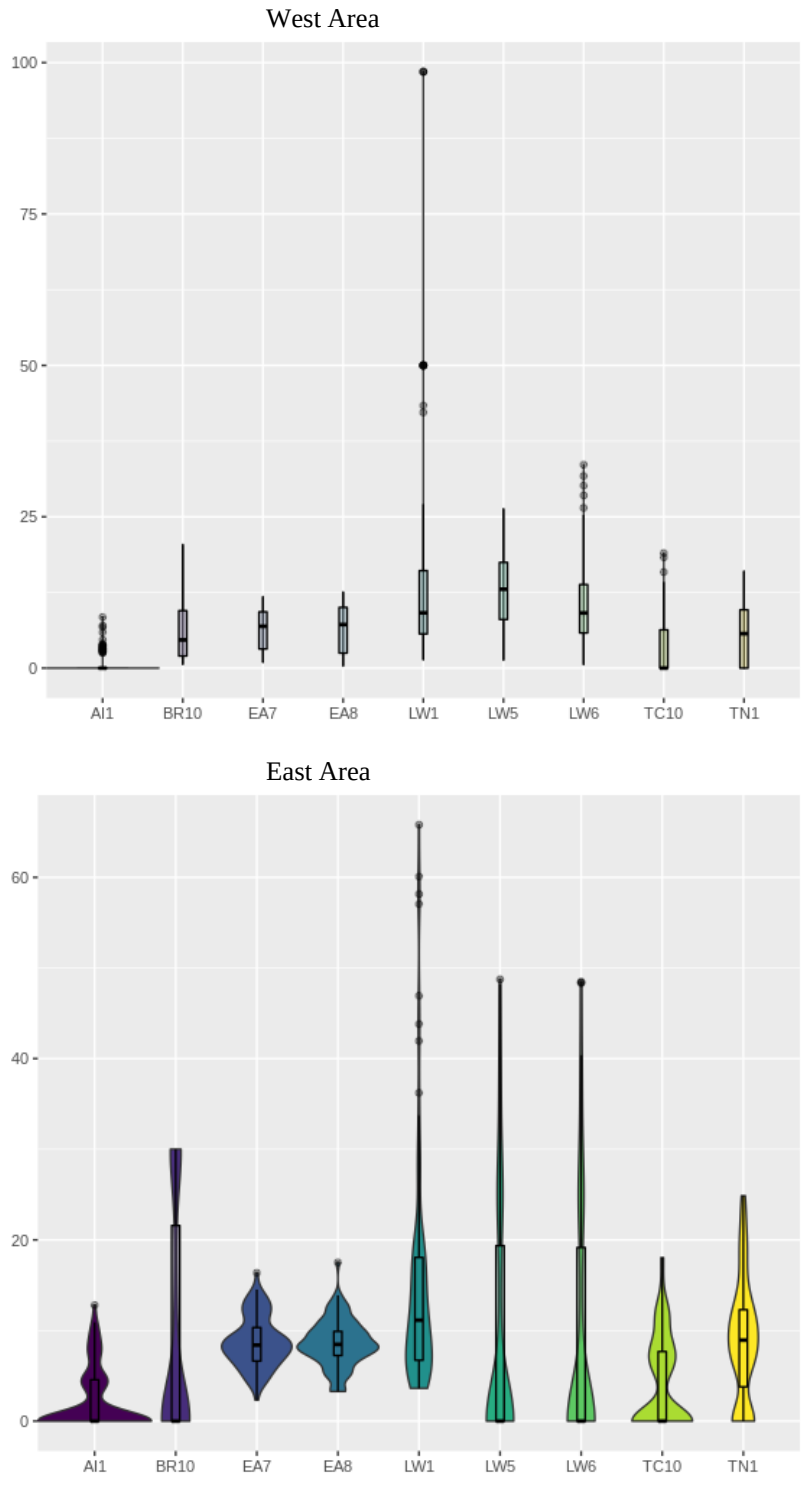


Figure 3. Yield variability (AAVC) of CMPs tuned to western stock Br30 = 1.

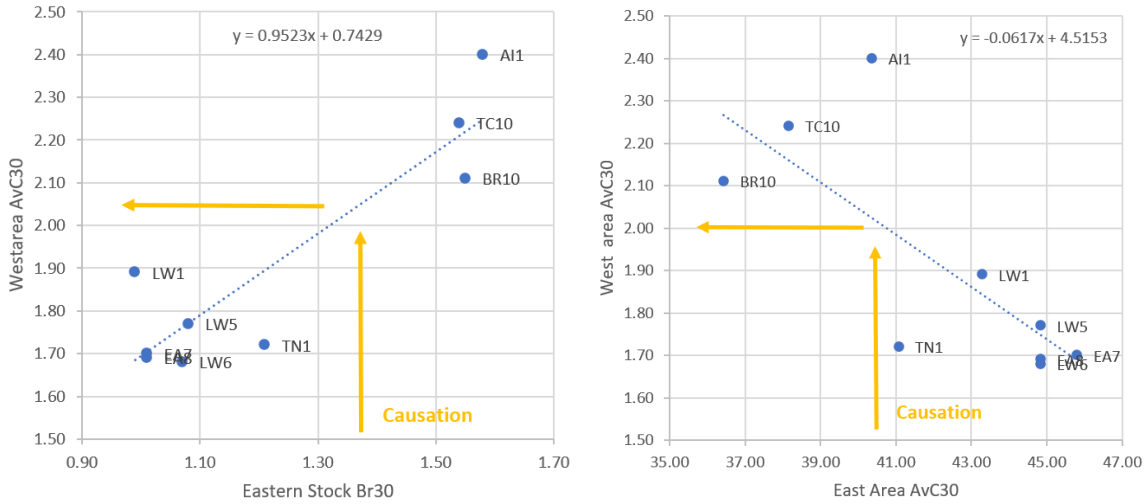


Figure 4. CMP performance trade-offs among stocks for reference set operating models and a tuning to western stock Br30 = 1. Care should be taken in the interpretation of this plot. Eastern Br30 and East area AvC30 outcomes are not responsive to catch levels in the West area. Once an eastern Br30 tuning is specified, it strongly determines what is possible in the West area and therefore even though a correlation is apparent, the causation runs almost entirely East to West.

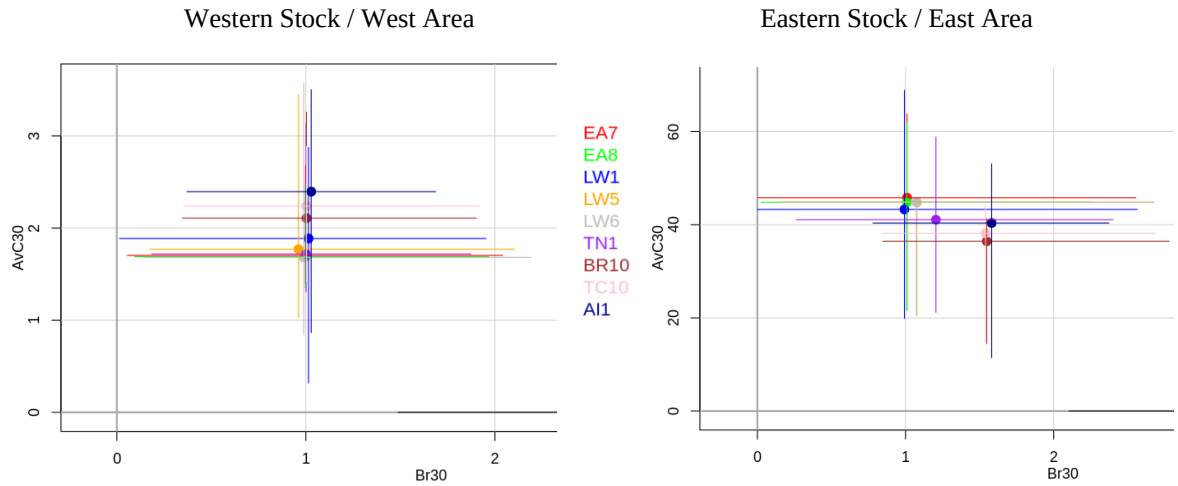


Figure 5. Biological – Yield performance trade-off among CMPs tuned to western Br30 = 1.00.

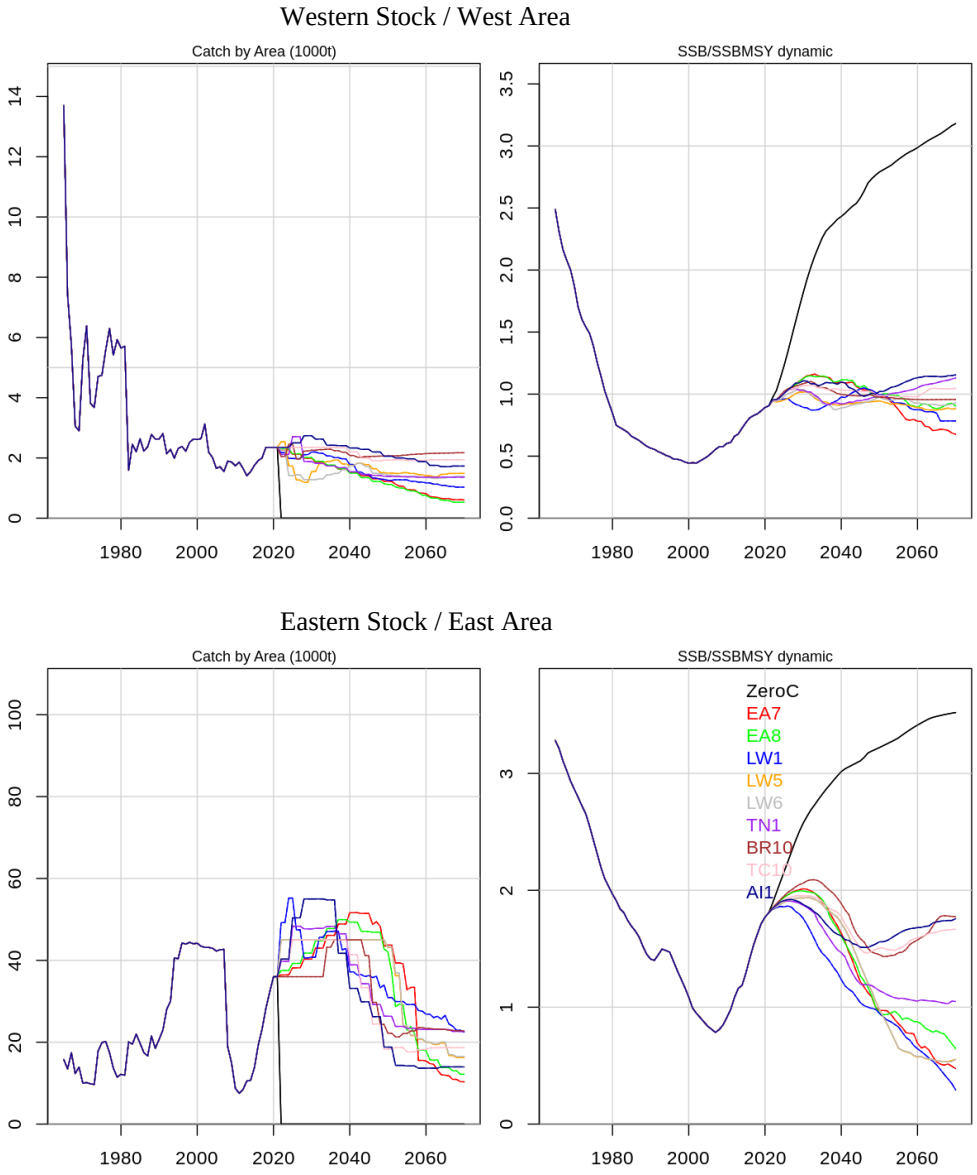


Figure 6a. Median projected catch and spawning stock biomass for CMPs tuned to western Br30=1.00.

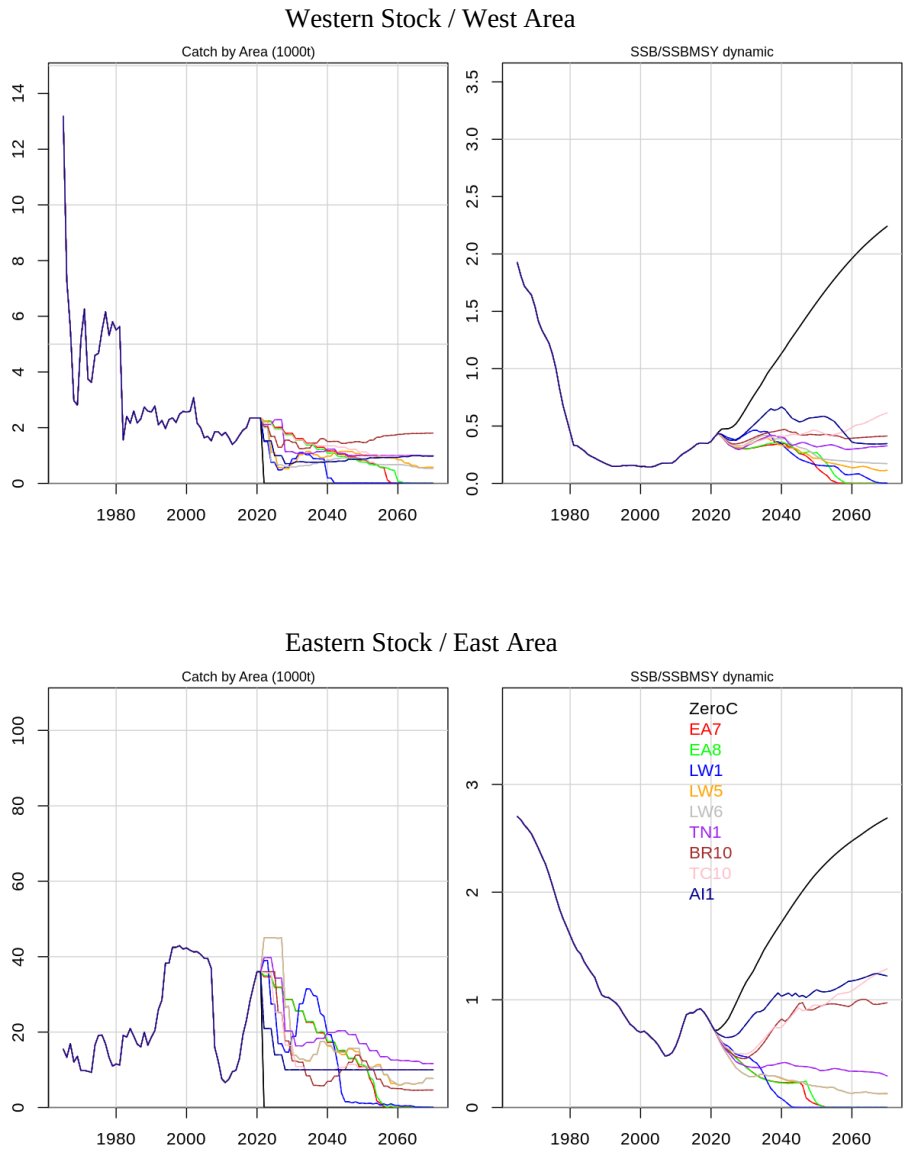


Figure 6b. 10th percentiles of projected catch and spawning stock biomass for CMPs tuned to western Br30=1.00.

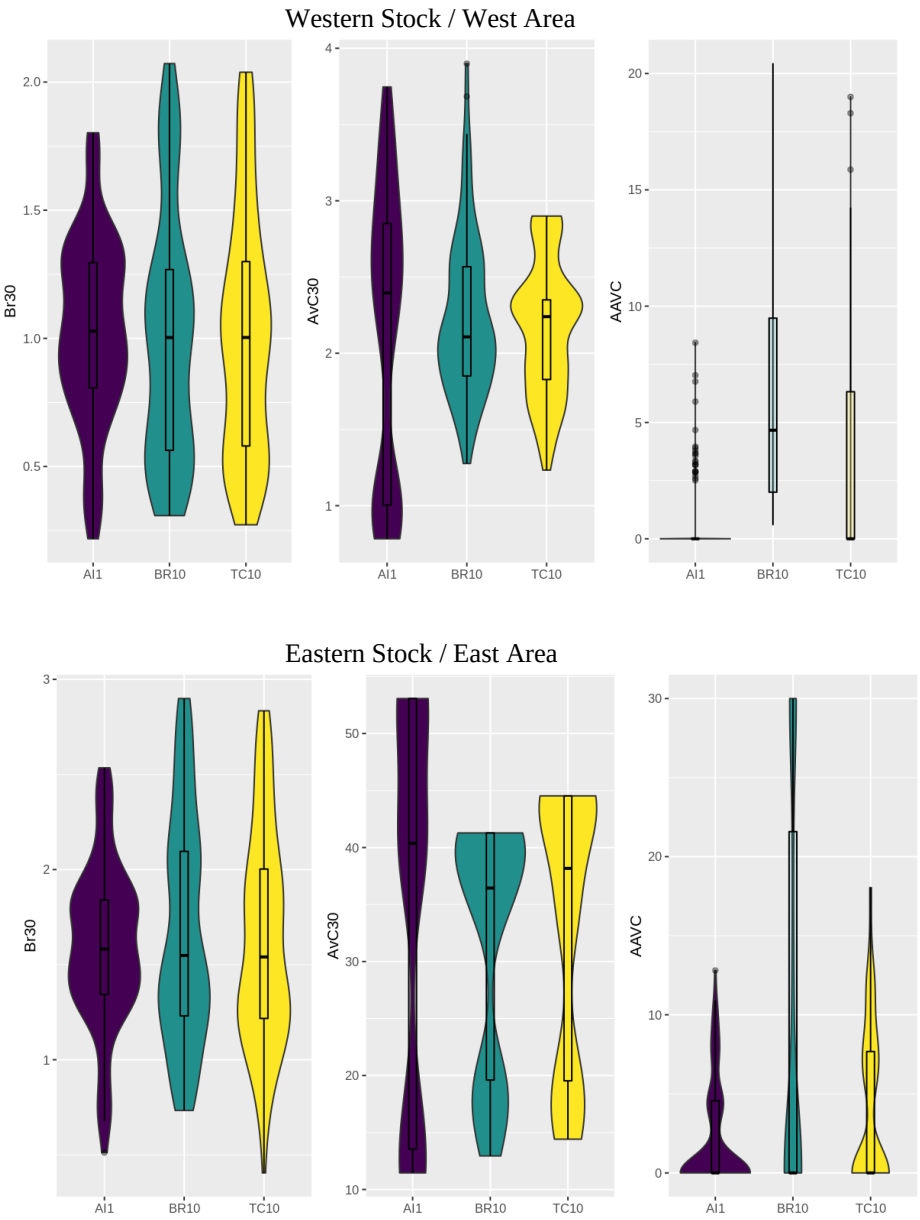


Figure 7. Comparative performance of CMPs that achieve highest western yield given tuning to western Br30 = 1.

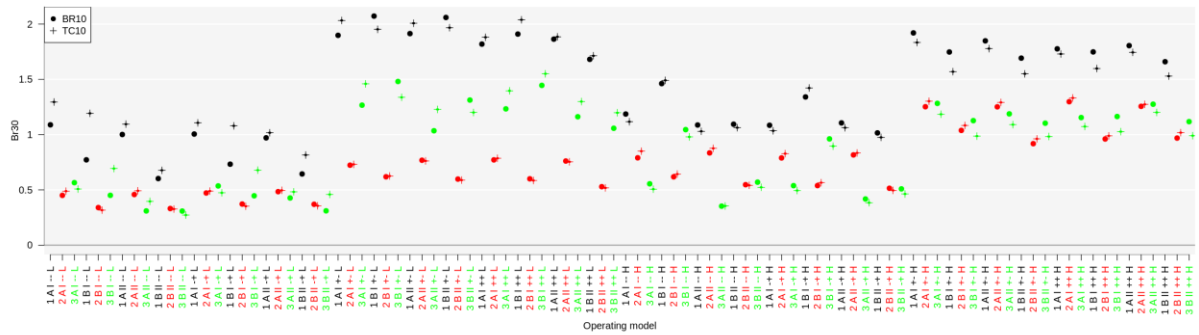


Figure 8. Comparison of recently updated CMPs (Br10 and TC10) that are both tuned to western Br30=1.

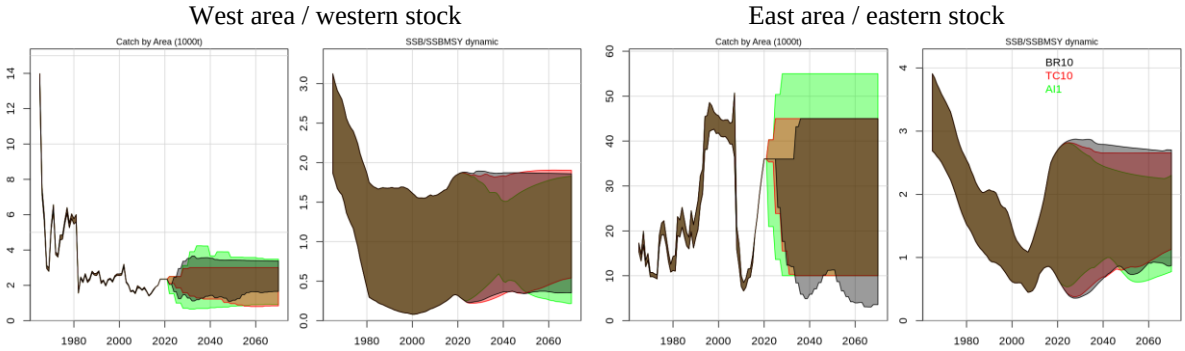


Figure 9. Comparison of projected catches and spawning stock biomass for three CMPs that obtain high yields given the tuning to western stock Br30=1.

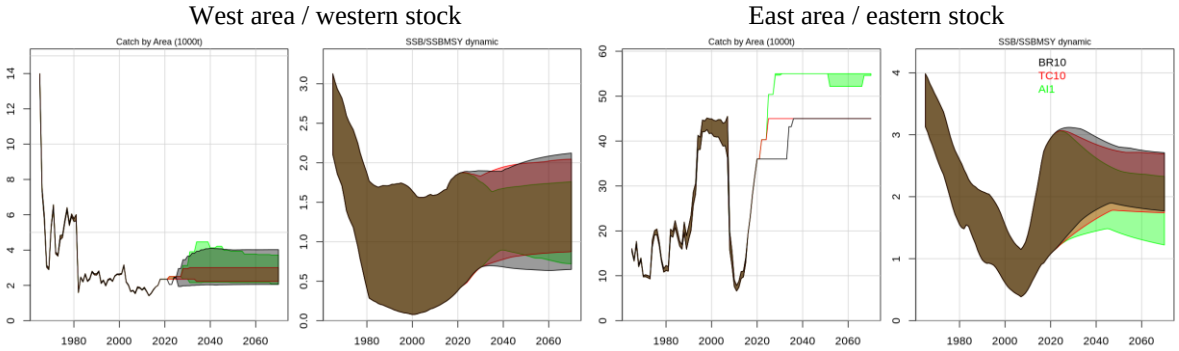


Figure 10a. As Figure 9 but for recruitment level 1 operating models (historical change in mean recruitment but no future change).

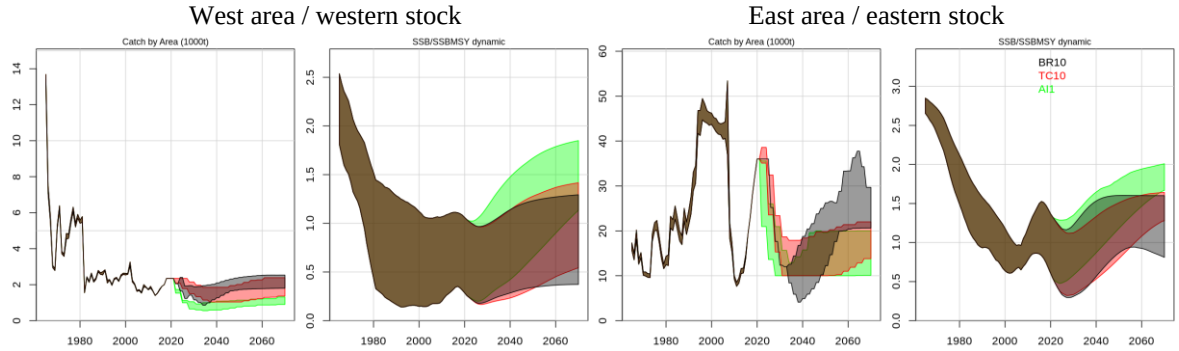


Figure 10b. As Figure 9 but for recruitment level 2 operating models (no historical or future change in mean recruitment).

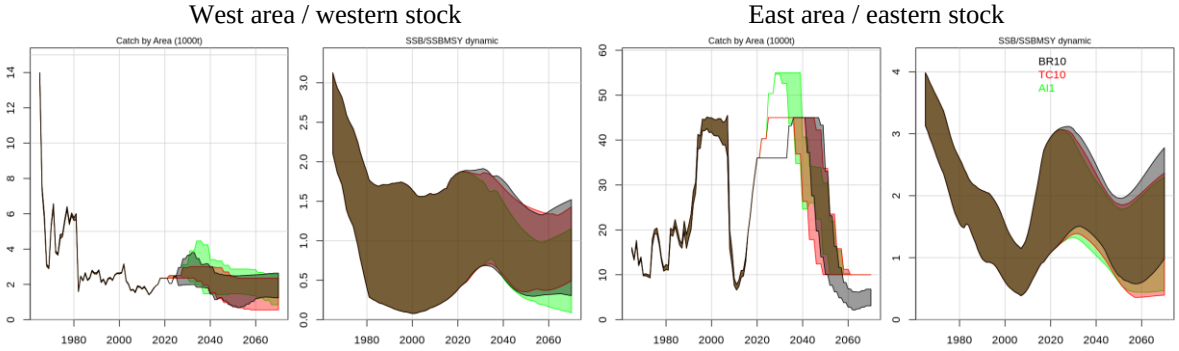


Figure 10c. As Figure 9 but for recruitment level 3 operating models (historical change in mean recruitment that reverts back in projection year 10).

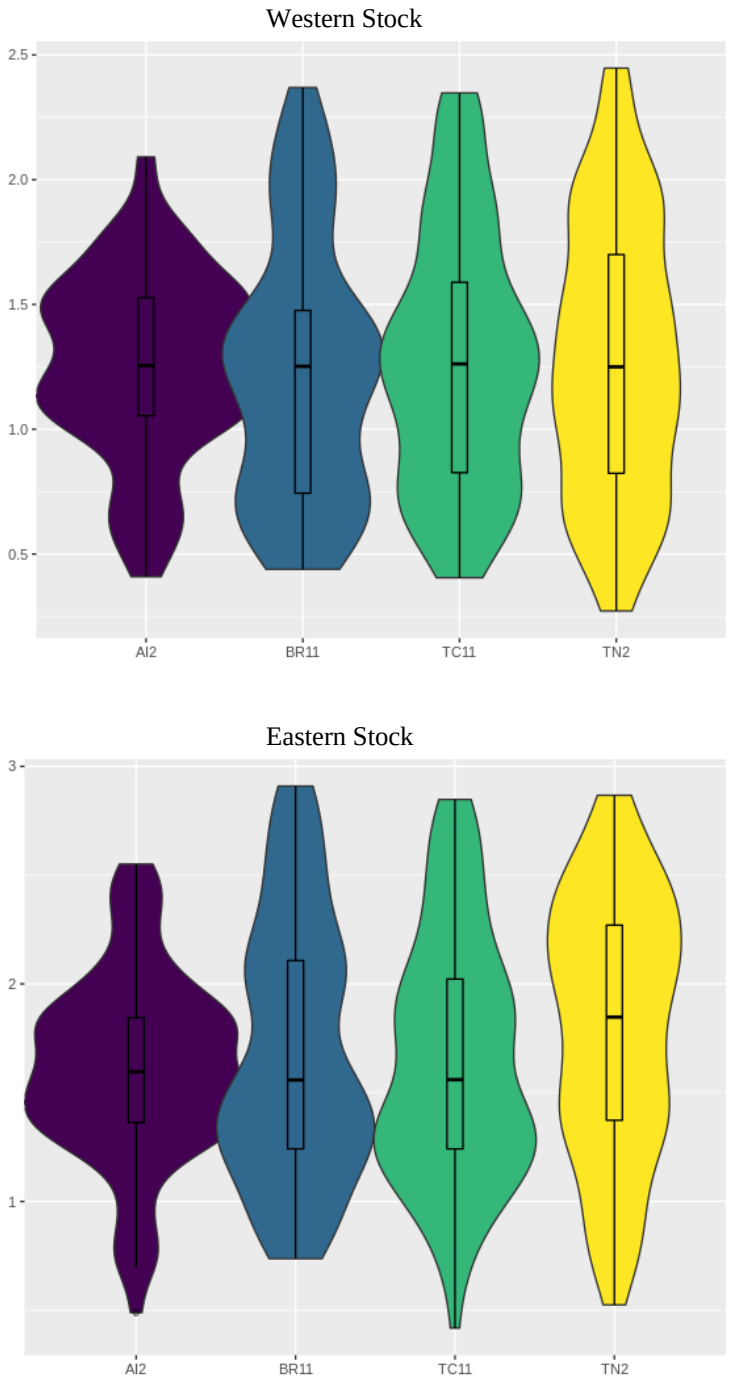


Figure 11a. Biological performance (Br30) of CMPs tuned to western stock Br30 = 1.25

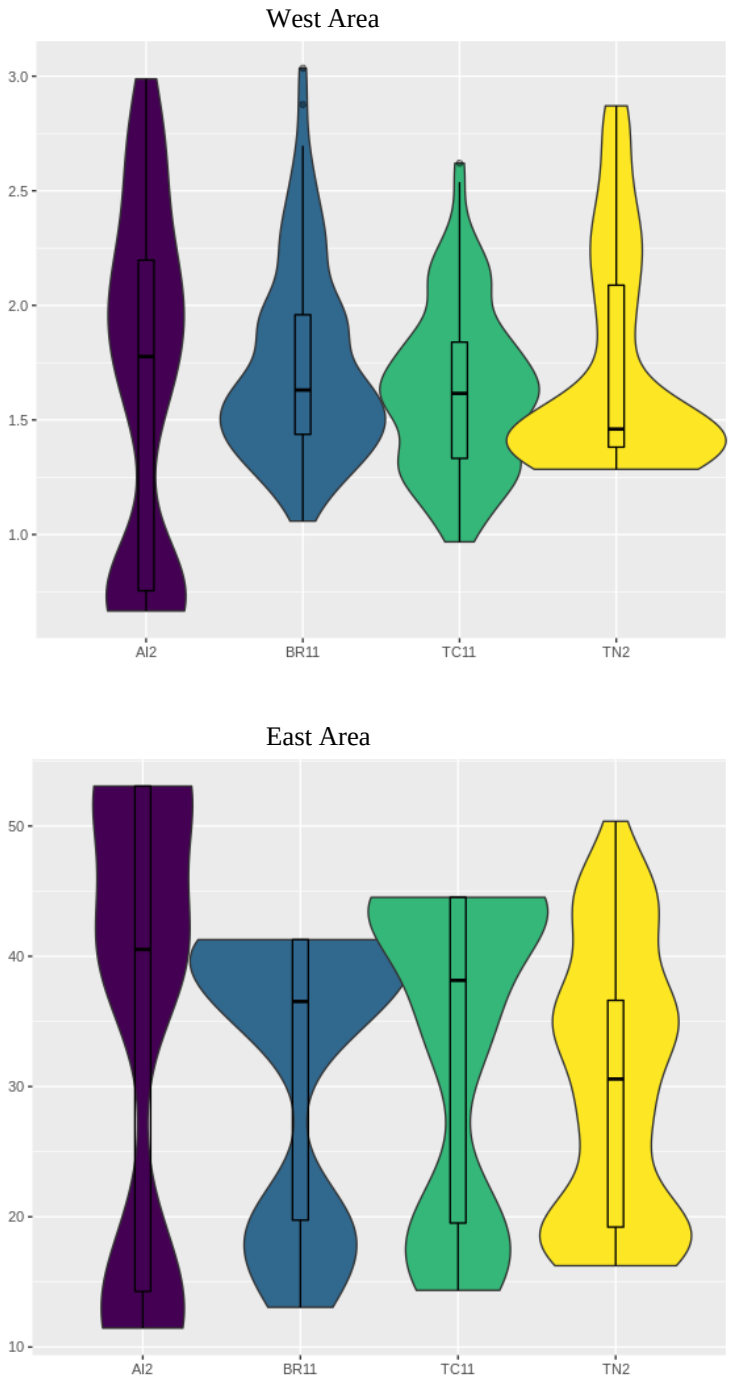
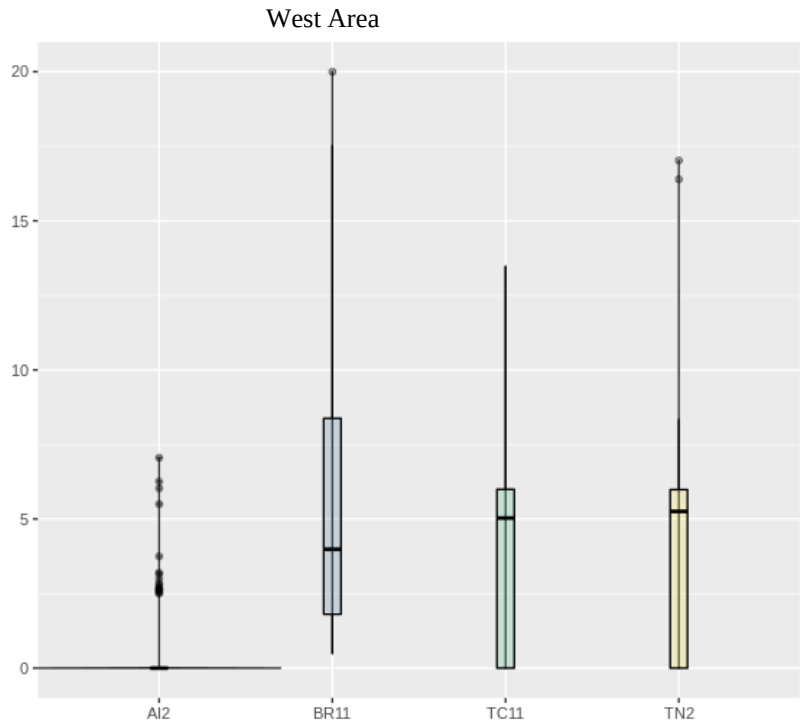


Figure 11b. Yield performance (AvC30) of CMPs tuned to western stock Br30 = 1.25



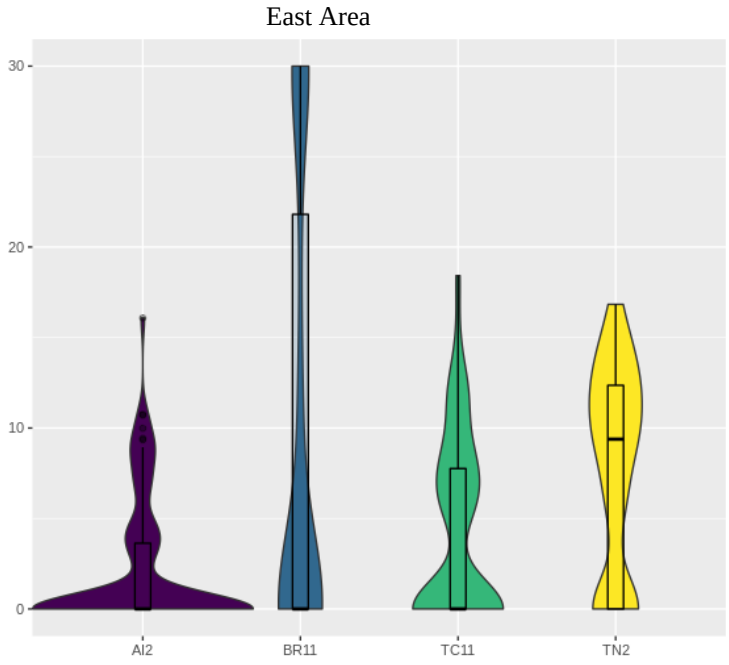


Figure 11c. Variability in yield (AAVC) of CMPs tuned to western stock Br30 = 1.25