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APPLICATION OF "FIXED PROPORTION" CANDIDATE MANAGEMENT PROCEDURES FOR NORTH ATLANTIC BLUEFIN TUNA USING OPERATING MODEL PACKAGE VERSION 5.2.3

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SUMMARY

Two adjustments are made to the simplest form of the fixed proportion CMPs developed earlier. Caps are placed on the TACs for both the West and the East area so as not reduce resource abundance unduly in circumstances where regime shifts occur. In addition, the TAC for the West area can be reduced further if an index, based on results from the Gulf of Mexico larval survey, drops below a specified threshold; this is necessary to prevent undue depletion in circumstances where the current abundance of the stock of tuna of western origin is low. Results for two variants of this new CMP (FXP_1 and FXP_2) are presented for the interim grid and primary robustness test Operating Models (OMs) (OM1-OM15 of Package version 5.2.3). These reflect more and less conservative approaches, and are intended as initial examples of this form of CMP; they are NOT intended as final candidates. Rather their purpose is to provide rough initial bounds on what variants might ultimately be considered to provide acceptable CMP performance. The results point to the importance of the assignment of plausibility to the scenario reflected by the primary robustness test of lower current western stock abundance. Assigning high plausibility to this can necessitate a reduction in average annual catches of some 1,000 t in the West area and about 10,000 t in the East area (at least as far as control rule parameter variants have been able to be explored – this has certainly been a limited exercise only to date). Results for further robustness tests are provided in an Annex. Suggestions for further exploration of control rule variations are made.

RÉSUMÉ

Deux ajustements sont apportés à la forme la plus simple des CMP à proportion fixe élaborées précédemment. Des plafonds sont imposés aux TAC pour les zones de l'Ouest et de l'Est afin de ne pas réduire indûment l'abondance de la ressource en cas de changement de régime. En outre, le TAC pour la zone Ouest peut encore être réduit si un indice, basé sur les résultats de la prospection larvaire du Golfe du Mexique, tombe en-dessous d'un seuil spécifié ; cela est nécessaire pour éviter un épuisement excessif dans des circonstances où l'abondance actuelle du stock de thonidés d'origine occidentale est faible. Les résultats de deux variantes de cette nouvelle CMP (FXP_1 et FXP_2) sont présentés pour la grille provisoire et les tests de robustesse des principaux modèles opérationnels (OM) (OM1-OM15 du paquet version 5.2.3). Ils reflètent des approches plus ou moins conservatrices et sont destinés à servir d'exemples initiaux de cette forme de CMP ; ils ne sont PAS destinés à être des candidats finaux. Leur but est plutôt de fournir des limites initiales approximatives sur les variantes qui pourraient en fin de compte être considérées comme offrant des performances acceptables de la CMP. Les résultats soulignent l'importance de l'attribution de la plausibilité au scénario reflété par le test de robustesse principal de la baisse actuelle de l'abondance du stock de l'Ouest. L'attribution d'une plausibilité élevée à ce scénario peut nécessiter une réduction des captures annuelles moyennes d'environ 1.000 t dans la zone Ouest et d'environ 10.000 t dans la zone Est (du moins en ce qui concerne les variantes des paramètres des règles de contrôle qui ont pu être explorées - cet exercice a certainement été limité à ce jour). Les résultats des autres tests de robustesse sont présentés en annexe. Des suggestions pour explorer plus à fond les variations des règles de contrôle sont faites.

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RESUMEN

Se realizan dos ajustes a la forma más simple de los CMP de proporción fija desarrollados antes. Se ponen límites a los TAC tanto de la zona occidental como oriental para no reducir la abundancia del recurso indebidamente en circunstancias en las que se produzca un cambio de régimen. Además, el TAC para la zona occidental puede reducirse aun más si un índice, en base a los resultados de la prospección de larvas del golfo de México, cae por debajo de un umbral especificado. Esto es necesario para impedir una merma indebida en circunstancias en las que la abundancia actual del stock de túnidos de origen occidental es baja. Se presentan los resultados para las dos variantes de este nuevo CMP (FXP_1 y FXP_2) para la matriz provisional y los principales modelos operativos de la prueba de robustez (OM1-OM15 del paquete versión 5.2.3). Estos reflejan enfoques más y menos conservadores, y están pensados como ejemplos iniciales de esta forma de CMP, NO están pensados como candidatos finales. Más bien, su propósito es proporcionar límites iniciales aproximados sobre qué variantes podrían considerarse al final para proporcionar un desempeño aceptable del CMP. Los resultados indican la importancia de asignar plausibilidad al escenario reflejado por el principal test de robustez de la menor abundancia actual del stock occidental. Asignando una plausibilidad elevada a esto puede requerir una reducción de las capturas anuales medias de unas 1.000 t en la zona occidental y de unas 10.000 t en la zona oriental (al menos hasta que hayan podido explorarse variantes del parámetro de la norma de control - esto, ciertamente, ha sido solo un ejercicio limitado hasta la fecha). Los resultados de más pruebas de robustez se facilitan en un Anexo. Se hacen sugerencias para una mayor exploración de las variaciones en la norma de control.

KEYWORDS

Management Strategy Evaluation, Candidate Management Procedure, Operating Model, Atlantic bluefin tuna, trade-off, plausibility

Introduction

This document extends the approach of Butterworth *et al.* (2018, 2019) in developing Candidate Management Procedures (CMPs) for the (two mixing stocks of the) North Atlantic Bluefin tuna resource. Two substantive changes are introduced to the simplest (intended) fixed proportion form of this approach; this is to provide satisfactory performance in circumstances of possible future regime shifts, and of the stock of western origin bluefin tuna currently being at a low level. A more and less conservative variant of this CMP is applied to the updated conditioned Operating Models (OMs) in the revised Package version 5.2.3.

Because that Package, following corrections, became available only very recently, the work reported in this document is somewhat limited, and relates to application of these CMPs under the Operating Models (OMs) of the interim grid (OM1 – OM12) and the primary robustness test (OM13 - OM15) only.

Methods

The methods applied here are essentially the same as detailed in Butterworth *et al.* (2018 and 2019).

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[3], and then taking a weighted average of the results for each index, where the weight is inversely proportional to the variance (σ^2) shown by that standardised index over the chosen years. The mathematical details are as follows:

[3] These years commence from 2011 (JPN_LL_NEAtl2), 2009 for FR_AER_SUV, 2012 for MED_LAR_SUV, 2010 for GBYP_AER_SUV, 2011 for JPN_LL_West2, 2007 for US_RR_66_114, 1979 for GOM_LAR_SUV and 2006 for CAN_ACO_SUV.

J_y is an average index over *n* series (*n*=4 for the East area and *n*=4 for the West area) [4]:

$$J_y = \frac{\sum_i^n w_i \times I_y^{i*}}{\sum_i^n w_i} \tag{1}$$

where

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

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

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

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

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

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

CMP specifications

The Fixed Proportion (FXP) CMPs tested set the TAC every second year simply as a multiple of the J_{av} value for the area at the time, 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:

$$TAC_{E,y} = \left(\frac{TAC_{E,2018}}{J_{E,2016}}\right) \cdot \alpha \cdot J_{av,y-2}^{E} \tag{3a}$$

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

If $TAC_{E,y} \leq 0.8 * TAC_{E,y-1}$ then $TAC_{E,y} = 0.8 * TAC_{E,y-1}$

For the West area:

$$TAC_{W,y} = \left(\frac{TAC_{W,2018}}{J_{W,2016}}\right) \cdot \beta \cdot J_{av,y-2}^{W} \tag{3b}$$

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

If $TAC_{W,y} \leq 0.8 * TAC_{W,y-1}$ then $TAC_{W,y} = 0.8 * TAC_{W,y-1}$

Note that in equation (3a), setting $\alpha = 1$ will amount to keeping the TAC the same as for 2018 until the abundance indices change. If α or $\beta > 1$ harvesting will be more intensive then at present and for α or $\beta < 1$ it will be less intensive.

Initial deterministic runs with these FXP CMPs immediately showed that some modifications were needed to this simple approach to obtain satisfactory performance across the OMs of the interim grid (OM1 – OM12) and the first robustness test (OM13 – OM15). First, to cater in particular for future possible regime shifts, it was necessary to impose caps on the maximum TAC that might be set for both the East and the West areas:

If $TAC_{W/E,y} \geq TAC_{W/E,max}$ then $TAC_{W/E,y} = TAC_{W/E,max}$ (4)

[4] For the French and Mediterranean aerial survey, there is no value for 2013 and 2015 respectively. For GBYP aerial survey there is no value for 2012, 2014 and 2016. For Mediterranean survey, Canadian acoustic survey, there is no value for 2016. These years were omitted from this averaging where relevant.

Secondly, in circumstances where the western stock abundance is low, the formulae above did not reduce the West area TAC sufficiently to promote stock recovery. To address this, the output from equations (3b) and (4) was modified further based only on the GOM_LAR_SUV index; this is used in isolation because it is the only one of the indices available for the West area which is related to the abundance of western origin tuna alone without being impacted by the presence of eastern origin fish as well. The modification is of the form where $TAC_{W,y}$ is altered as follows:

$$TAC^*_{W,y} = X_{W,y} TAC_{W,y} \tag{5}$$

with

$$X_{W,y} = \begin{cases} 1 & \text{if } I^{*smooth}_{y-2} \geq T \\ I^{*smooth}_{y-2} & \text{if } I^{*smooth}_{y-2} < T \end{cases} \tag{6}$$

where $I^{*smooth}_{y}$ is a smoothed normalised index based on the GOM_LAR_SUV index (I_y):

$$I^*_y = I_y \Big/ \left(\frac{1}{y_2 - y_1 + 1} \sum_{y'=y_1}^{y_2} I_{y'} \right) \tag{7}$$

This normalised index is then smoothed:

$$I^{*smooth}_{y} = \frac{1}{3}\left(I^*_y + I^*_{y-1} + I^*_{y-2} \right) \tag{8}$$

The TAC formulae for both FXP as originally conceived (equation (3)), and then with both these modifications added, are illustrated in **Figure 1**.

For the deterministic case, CMPs have been run under selections from the Package for deterministic OMs with *Perfect observation* and with no implementation error. For the stochastic case, CMPs are run under selections from the Package for normal OMs with *Good observation* and with no implementation error.

Because of late availability of the final Package, only limited investigations have been possible, with many of these having to be based on deterministic projections

Results

The values of the control parameters chosen for FXP_1 and FXP_2 are as follows:

FXP_1: α = 0.5; β = 0.5; $TAC_{W,max}$ = 4 000 mt; $TAC_{E,max}$ = 30 000 mt; T=1.0
FXP_2: α = 1.0; β = 1.0; $TAC_{W,max}$ = 4 000 mt; $TAC_{E,max}$ = 30 000 mt; T=1.0

Table 1 shows deterministic results for the interim grid (OM1 – OM12) and the primary robustness test (OM13 - OM15) scenarios, i.e. "perfect future information" situations where the abundance indices used are exactly proportional to the underlying true abundances, and there is no variability about the stock-recruitment relationship which applies. These results are shown graphically in **Figure 2**.

Table 2 then repeats these results for "stochastic" scenarios, where the future resource index values generated do include noise about their relationships with the underlying abundance, and recruitment incorporates variations about the associated stock recruitment relationship. **Figure 3** shows these results graphically, except that to avoid cluttering the plots, probability intervals are shown for the FXP_2 CMP only.

These Tables and Figures also include results for a "C=0" scenario, under which once management starts, future catches are set equal to zero – though note that this is after the first three years of the projection period for which the actual catches made or TACs already set have been taken into account. Values of Br0 are also reported; these are depletions relative to dynamic B_{MSY} at the start of the projection period, and they provide an indication of whether the resource level (as measured in this "relative" way) has increased or fallen under the impact of the CMP concerned.

Figure 4 shows the deterministic projections for the catch and SSB under the C=0 scenario and the two CMPs for the three OMs that comprise the primary robustness test (OM13 – OM15).

Deterministic results for robustness tests ROM_1 to ROM_30 are provided in the Annex.

Discussion

Initial explorations of potential CMPs were first based on consideration of deterministic results (if a CMP does not perform adequately given perfect information, it is hardly likely to do so once realistic levels of noise are added to the abundance indices). Furthermore, the “C=0” scenario was run to provide “upper bounds” on the final (dynamic) depletion possible, so as to indicate the best possible outcome from the perspective of the resources alone.

From these explorations, it immediately became evident that the primary robustness trials (and especially OM14 – a variant of 2BI) produced much more pessimistic outcomes from a western stock depletion perspective, so that the authors’ initial focus has been to develop CMPs that avoid leaving a western stock well below its dynamic B_{MSY} level under OM14 at the end of the 30-year projection period.

The control parameter values for FXP_1 were chosen to meet that objective as seemed best possible without seriously compromising catches for the various OMs of the interim grid. The corresponding control parameter values for FXP_2 were then varied from those for FXP_1 to achieve higher catches for those interim grid OMs, though at the expense of greater depletion of the western stock under OM14; this is as might be considered appropriate if subsequently OM14 is accorded a low plausibility weighting.

Thus FXP_1 and FXP_2 are not intended as “finalists” for the ultimate MP choice process. Rather their purpose is to provide rough initial bounds on what might ultimately be considered to provide acceptable CMP performance. Consequently, the choice of the values for the T and maximum TAC control parameters should also not be seen as final, as in the time available a full search of control parameter space has not been possible. Note that T was introduced to better avoid undue depletion of the western stock under especially the OM14 scenario. The caps on the TACs were to avoid these TACs getting too large to be able to avoid undue depletion in the event of a future regime change.

Results in **Tables 1 and 2**, and in the respectively corresponding **Figures 2 and 3**, do show that (for the stochastic projections) for the western stock under FXP_1, the median abundance is below B_{MSY} only for OM14, though if lower 5%-iles are considered this can occur also for OM13 and the interim grid scenario OM5 (2BI). For the less risk averse FXP_2, OM13 and OM5 results are also below B_{MSY} in median terms. For the eastern stock, there are no scenarios with a median abundance below B_{MSY} for either FXP_1 or FXP_2 after 30 years; however, the lower 5%-ile falls below B_{MSY} for five scenarios under FXP_1 and a further four scenarios under FXP_2.

Naturally, the more conservative FXP_1 leads to lower catches than does FXP_2. For the West area, average annual catches are from about 500 to 1 000 mt less under FXP_1 than the some 3 000 to 3 500 mt taken under FXP_2. For the East area, an average catch (in median terms) of slightly less than 30 000 mt under FXP_2 drops to about 20 000 mt under FXP_1.

The deterministic TAC and SSB plots shown in **Figure 4** for the three scenarios of the primary robustness test illustrate most of the major features seen for the interim grid scenarios. TACs generally climb to their maxima fairly soon, though in some cases after an initial drop for the more conservative FXP_1 CMP. There can be large drops after a few decades in some cases, particularly when there is a shift to a less productive regime for the eastern origin stock (which has implications also for the number of tuna available in the West area). A concern sometimes for scenarios with this future eastern stock regime shift is a continued decline of the eastern stock to below B_{MSY} after more than 30 years into the future.

Of the robustness tests results shown in the Annex, test ROM_2 is the only one which leads to some conservation concern. This sees the western stock still well below B_{MSY} at the end of the projection period.

Conclusion and further analyses

The results of this document point to the importance of the assignment of plausibility to the scenario reflected by the primary robustness test of lower current western stock abundance. Assigning high plausibility to this can necessitate a reduction in average annual catches of some 1 000 mt in the West area and about 10 000 mt in the East area (at least as far as this document has been able to explore control rule parameter variants – this has certainly been a limited exercise only to date).

The further robustness tests in the Package are currently under process, and their results under the two CMPs put forward here will hopefully soon be available in the form of a separate Annex to this document.

Further work will likely focus on three areas.

1. Further exploration of the space of values for the existing control parameters to ascertain whether improved trade-offs in performance can be obtained.

2. Possible incorporation of an “X”-like (parabolic) adjustment – see equation (5) – for calculation of the East as well as the West area TAC, to try to avoid undue depletion of the eastern stock in circumstances of a shift to a less productive eastern stock regime in the future.

3. In addition to the equation (5) adjustment, relaxing the constraint on the maximum percentage reduction in TAC if indices drop below some threshold, where this is to allow for bigger TAC reductions when needed to try to counter a resource decline.

References

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Table 1. Deterministic results for Br30 and AvC30 for two CMPs: FXP_1 (α=0.5, β=0.5) and for FXP_2 (α=1.0, β=1.0) for OM1 to OM15. Note that the reason that AvC30 is not zero for the C=0 results is that the catches for the first three years of the 30-year projection period are already fixed at the amounts landed or TACs already set and so are included in the average; after those first three years the subsequent projected catches are zero. Note that Br results refer to stocks whereas AvC results refer to areas.

				West							East						
				Br0	**Br30**			**AvC30**			**Br0**	**Br30**				**AvC30**	
					C=0	**FXP_1**	**FXP_2**	**C=0**	**FXP_1**	**FXP_2**		**C=0**	**FXP_1**	**FXP_2**	**C=0**	**FXP_1**	**FXP_2**
A-group	OM	1	1AI	2.343	2.788	2.160	1.901	0.223	2.867	3.624	1.947	2.963	2.501	2.092	2.652	19.548	29.546
		7	1AII	3.099	2.942	2.576	2.402	0.223	2.796	3.621	1.926	2.959	2.490	2.083	2.652	19.675	29.546
		2	2AI	2.344	2.311	1.963	1.733	0.223	2.610	3.616	2.100	2.349	2.017	1.628	2.652	17.662	27.829
		8	2AII	2.811	2.452	2.268	2.135	0.223	2.551	3.614	2.226	2.388	2.088	1.725	2.652	17.271	27.366
		3	3AI	2.343	2.820	2.306	2.091	0.223	3.078	3.625	1.947	2.541	1.811	1.210	2.652	19.603	28.674
		9	3AII	3.099	2.954	2.593	2.451	0.223	3.078	3.622	1.926	2.557	1.857	1.243	2.652	19.086	28.381
B-group		4	1BI	1.342	2.794	1.722	1.439	0.223	3.078	3.631	1.587	2.752	2.259	1.948	2.652	21.462	29.546
		10	1BII	2.188	3.142	2.396	2.176	0.223	3.075	3.629	1.644	2.703	2.175	1.859	2.652	21.745	29.546
		5	2BI	1.356	1.850	1.227	0.852	0.223	2.615	3.579	2.768	2.245	1.937	1.560	2.652	17.612	27.760
		11	2BII	2.921	2.637	2.451	2.318	0.223	2.548	3.600	3.534	2.351	2.093	1.761	2.652	17.271	28.636
		6	3BI	1.343	2.966	2.216	1.936	0.223	3.078	3.632	1.587	2.341	1.693	1.306	2.652	21.868	29.546
		12	3BII	2.188	3.217	2.639	2.424	0.223	3.078	3.629	1.644	2.262	1.597	1.166	2.652	21.441	29.494
ROM		13	1wBI		2.358	1.106	0.820	0.223	3.111	3.638		2.768	2.263	1.956	2.652	21.718	29.546
		14	2wBI		1.077	0.410	0.149	0.223	2.534	3.204		2.230	1.910	1.527	2.652	17.730	27.640
		15	3wBI		2.592	1.720	1.427	0.223	3.111	3.638		2.360	1.675	1.326	2.652	22.661	29.546

Legend: 1/2/3 reflect different stock-recruitment function scenarios, with 1 involving past regime shifts, and 3 further such shifts in the future
A/B younger spawning and high M/older spawning and low M
I/II have low/high E-tag weight (which in turn impacts the extent of mixing)
ROM greater precision in the GOM larval survey index to create scenarios with lower current western stock status

Table 2a. Stochastic results for Br30 and AvC30 for FXP_1 (α=0.5, β=0.5) for OM1 to OM15. The results shown are medians with 5%- and 95%-ile values shown in parenthesis. For reasons of time constraints, the stochastic results for C =0 are not yet available; to assist as a broad guide, their deterministic equivalents have been shown in the meantime. Note that Br results refer to stocks whereas AvC results refer to areas.

				West					
				Br0	**Br30**			**AvC30**	
					C=0	**FXP_1**	**FXP_2**	**FXP_1**	**FXP_2**
A-group	OM	1	1AI	2.343	2.857	2.074(1.49, 3.154)	1.828(1.199, 2.755)	2.61(1.405, 3.109)	3.476(2.134, 3.638)
		7	1AII	3.099	2.944	2.497(1.574, 3.718)	2.281(1.404, 3.423)	2.389(1.294, 2.914)	3.442(1.978, 3.638)
		2	2AI	2.344	2.506	2.051(1.146, 3.143)	1.824(1.036, 2.908)	2.346(1.469, 2.91)	3.443(2.411, 3.638)
		8	2AII	2.811	2.621	2.345(1.335, 3.487)	2.146(1.259, 3.295)	2.286(1.39, 2.789)	3.405(2.253, 3.638)
		3	3AI	2.343	2.908	2.232(1.702, 3.114)	1.996(1.461, 2.841)	3.078(2.731, 3.295)	3.556(3.323, 3.638)
		9	3AII	3.099	2.961	2.47(1.858, 3.38)	2.334(1.693, 3.235)	3.068(2.435, 3.242)	3.518(3.214, 3.638)
B-group		4	1BI	1.342	3.015	1.737(1.336, 2.516)	1.375(1, 2.005)	2.906(1.723, 3.236)	3.527(2.607, 3.638)
		10	1BII	2.188	3.273	2.415(1.745, 3.336)	2.16(1.484, 2.929)	2.75(1.512, 3.179)	3.509(2.321, 3.638)
		5	2BI	1.356	2.111	1.368(0.773, 2.186)	0.962(0.485, 1.613)	2.077(1.477, 2.546)	3.24(2.287, 3.622)
		11	2BII	2.921	2.731	2.483(1.699, 3.665)	2.328(1.56, 3.444)	2.097(1.28, 2.519)	3.327(2.115, 3.638)
		6	3BI	1.342	3.168	2.168(1.649, 3.085)	1.923(1.373, 2.802)	3.078(2.752, 3.297)	3.557(3.274, 3.638)
		12	3BII	2.188	3.331	2.571(1.888, 3.583)	2.417(1.68, 3.354)	3.078(2.635, 3.303)	3.565(3.169, 3.638)
ROM		13	1wBI		2.668	1.053(0.707, 1.653)	0.749(0.452, 1.249)	3.077(2.141, 3.329)	3.57(2.771, 3.638)
		14	2wBI		1.402	0.502(0.221, 1.082)	0.187(0.053, 0.595)	2.072(1.519, 2.603)	3.023(2.068, 3.562)
		15	3wBI		2.813	1.625(1.167, 2.451)	1.366(0.918, 2.07)	3.078(2.752, 3.345)	3.597(3.285, 3.638)

Table 2b. Stochastic results for Br30 and AvC30 for FXP_2 (α=1.0, β=1.0) for OM1 to OM15. The results shown are medians with 5%- and 95%-ile values shown in parenthesis. For reasons of time constraints, the stochastic results for C =0 are not yet available; to assist as a broad guide, their deterministic equivalents have been shown in the meantime. Note that Br results refer to stocks whereas AvC results refer to areas.

				East					
				Br0	Br30			AvC30	
					C=0	FXP_1	FXP_2	FXP_1	FXP_2
A-group	OM	1	1AI	1.947	3.157	2.385(1.738, 3.306)	2.012(1.403, 2.946)	19.694 (15.82, 24.378)	29.054(24.692,29.546)
		7	1AII	1.926	3.112	2.421(1.666, 3.558)	2.071(1.319, 3.148)	20.4 (16.013, 24.403)	29.328(25.596,29.546)
		2	2AI	2.100	2.297	1.797(1.003, 2.809)	1.524(0.66, 2.606)	19.629 (15.853, 24.949)	28.625(24.615,29.546)
		8	2AII	2.226	2.306	1.81(0.86, 2.891)	1.39(0.264, 2.595)	18.754 (15.039,24.317)	27.884(22.899,29.546)
		3	3AI	1.947	2.790	1.577(1.021, 2.326)	1.072(0.473, 1.731)	19.586 (16.172, 24.593)	28.438(25.292, 29.546)
		9	3AII	1.926	2.827	1.706(1.147, 2.575)	1.141(0.618, 2.037)	20.037 (15.962, 24.055)	28.336(25.269, 29.546)
B-group		4	1BI	1.587	2.955	2.257(1.632, 3.105)	1.958(1.322, 2.808)	21.819 (17.011, 25.857)	29.546(27.2, 29.546)
		10	1BII	1.644	2.899	2.145(1.474, 3.016)	1.836(1.146, 2.752)	21.715 (16.668, 26.002)	29.544(26.408, 29.546)
		5	2BI	2.768	2.379	1.824(0.796, 2.792)	1.524(0.477, 2.535)	19.828 (15.723, 26.496)	29.087(24.491, 29.546)
		11	2BII	3.534	2.421	1.905(0.758, 2.91)	1.306(0.581, 2.616)	19.126 (15.175, 25.684)	28.481(23.512, 29.546)
		6	3BI	1.587	2.626	1.598(1.081, 2.428)	1.323(0.711, 2.146)	22.622 (18.021, 26.364)	29.512(28.247, 29.546)
		12	3BII	1.644	2.508	1.518(0.925, 2.369)	1.146(0.582, 1.992)	21.654 (17.167, 26.299)	29.388(27.201, 29.546)
ROM		13	1wBI		3.005	2.256(1.679, 3.038)	1.963(1.379, 2.679)	21.817 (17.022, 26.088)	29.546(26.845, 29.546)
		14	2wBI		2.358	1.787(0.697, 2.73)	1.438(0.478, 2.44)	20.157 (15.857, 26.797)	28.945(24.589, 29.546)
		15	3wBI		2.597	1.578(1.064, 2.283)	1.278(0.785, 2.03)	23.796 (19.519, 26.839)	29.546(28.412, 29.546)

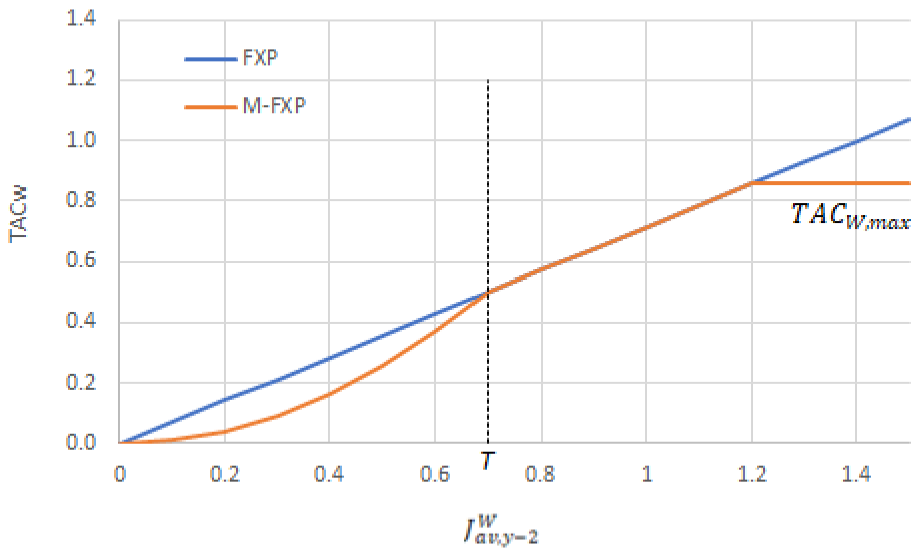

Figure 1. Illustrative relationship of TAC_W (TAC set for the West area) against J^W (the index for the West area) for FXP (equation (3b) and its modified form denoted here at M-FXP). Note that the plot is drawn (in the interests of simplicity) as if the index for all West area indices combined was the same as that for the Gulf of Mexico larval index only, but in application the parabolic form of the latter for $J^W < T$ relates to the Gulf of Mexico larval index only.

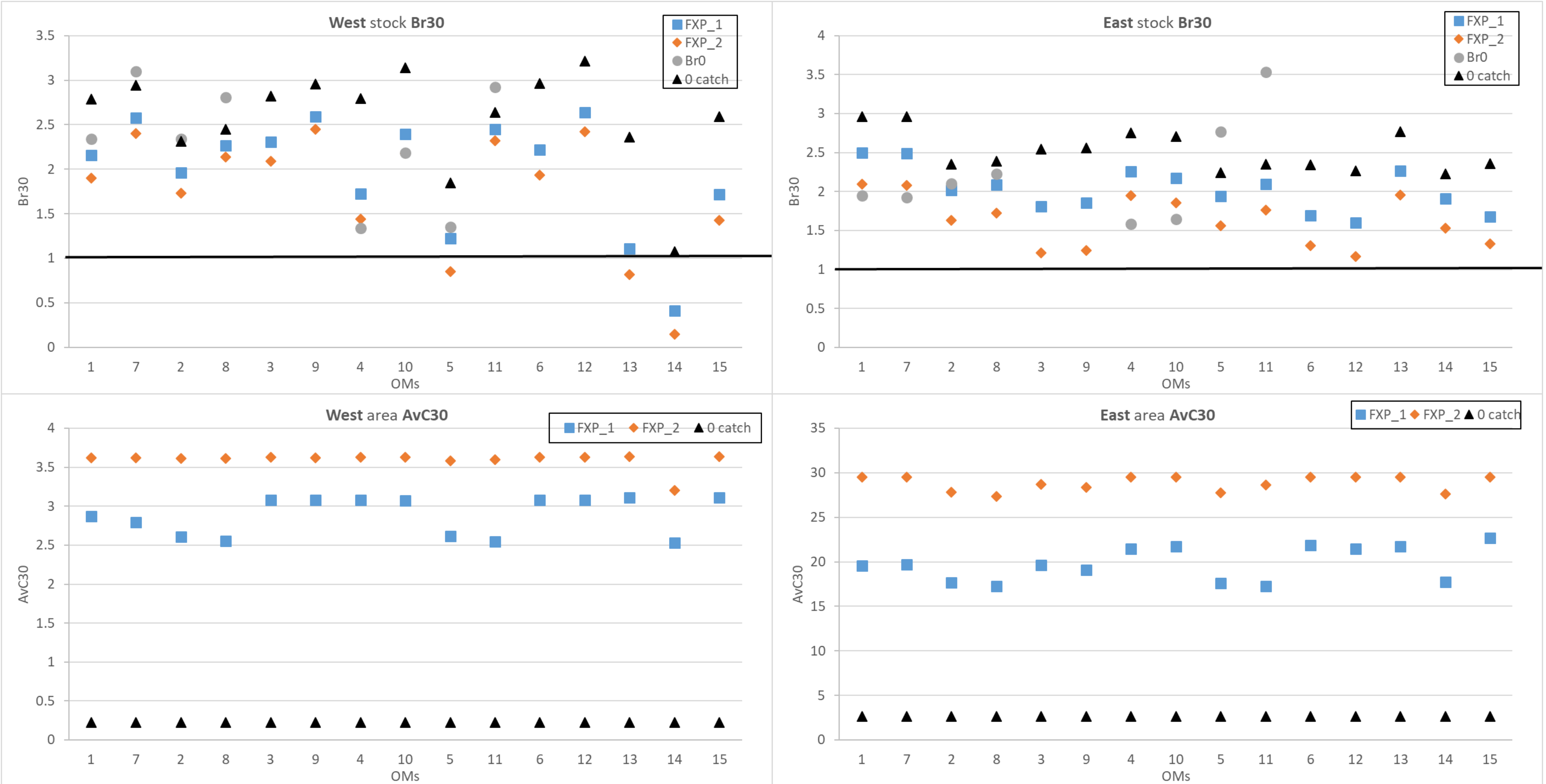

Figure 2. Deterministic results for Br30 and AvC30 for "0 catch" scenario and for two CMPs: FXP_1 (α=0.5, β=0.5) and for FXP_2 (α=1.0, β=1.0) for OM1 to OM15. Note that the reason that AvC30 is not zero for the "0 catch" results is that the catches for the first three years of the 30-year projection period are already fixed at the amounts landed or TACs already set and so are included in the average; after those first three years the subsequent projected catches are zero.

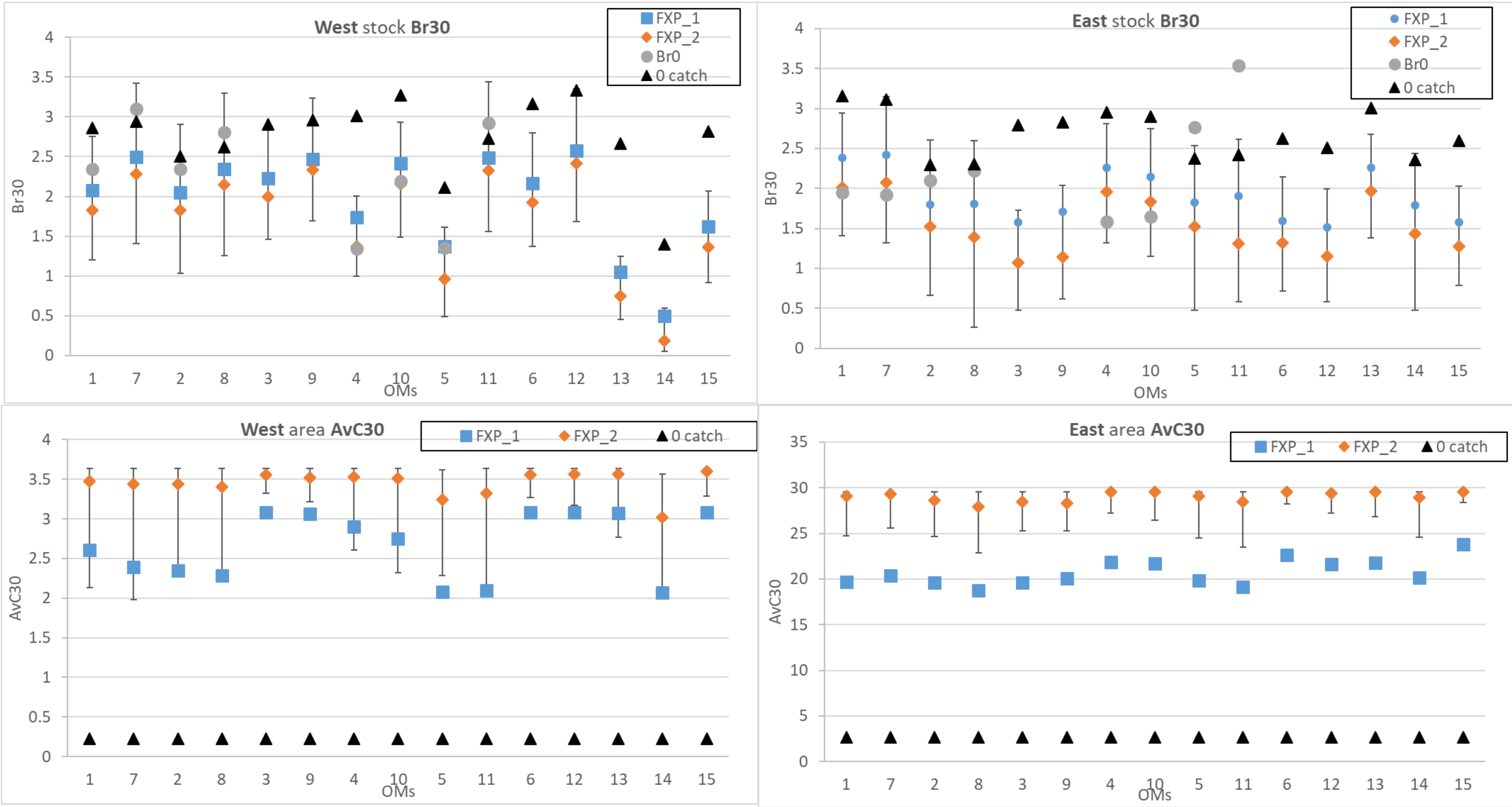

Figure 3. Stochastic results for Br30 and AvC30 for "0 catch" scenario and for two CMPs: FXP_1 (α=0.5, β=0.5) and for FXP_2 (α=1.0, β=1.0) for OM1 to OM15. Medians are shown except that for FXP_2 the 90% PIs are also shown.

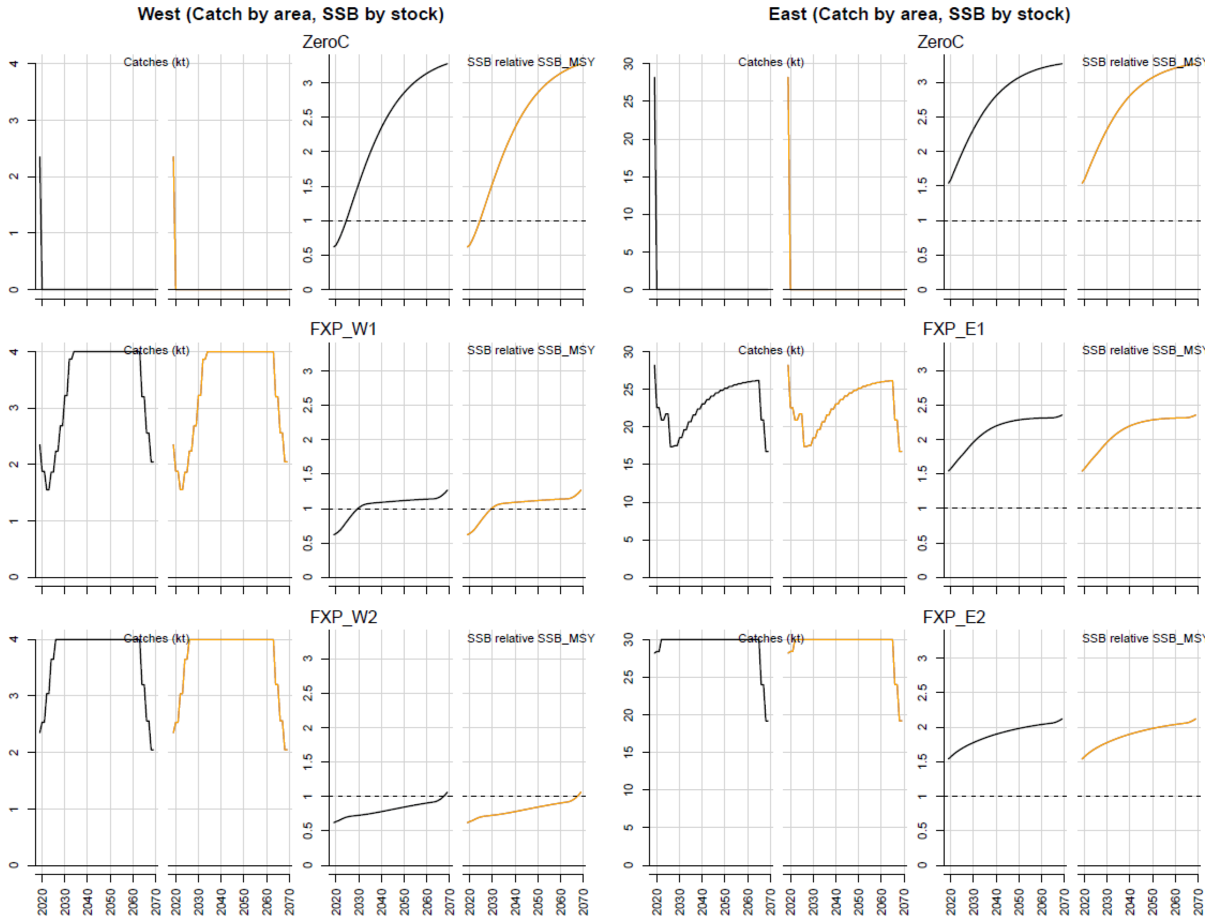

Figure 4a. Deterministic catch and SSB projections for OM13 for zero catch, FXP_1 and FXP_2.

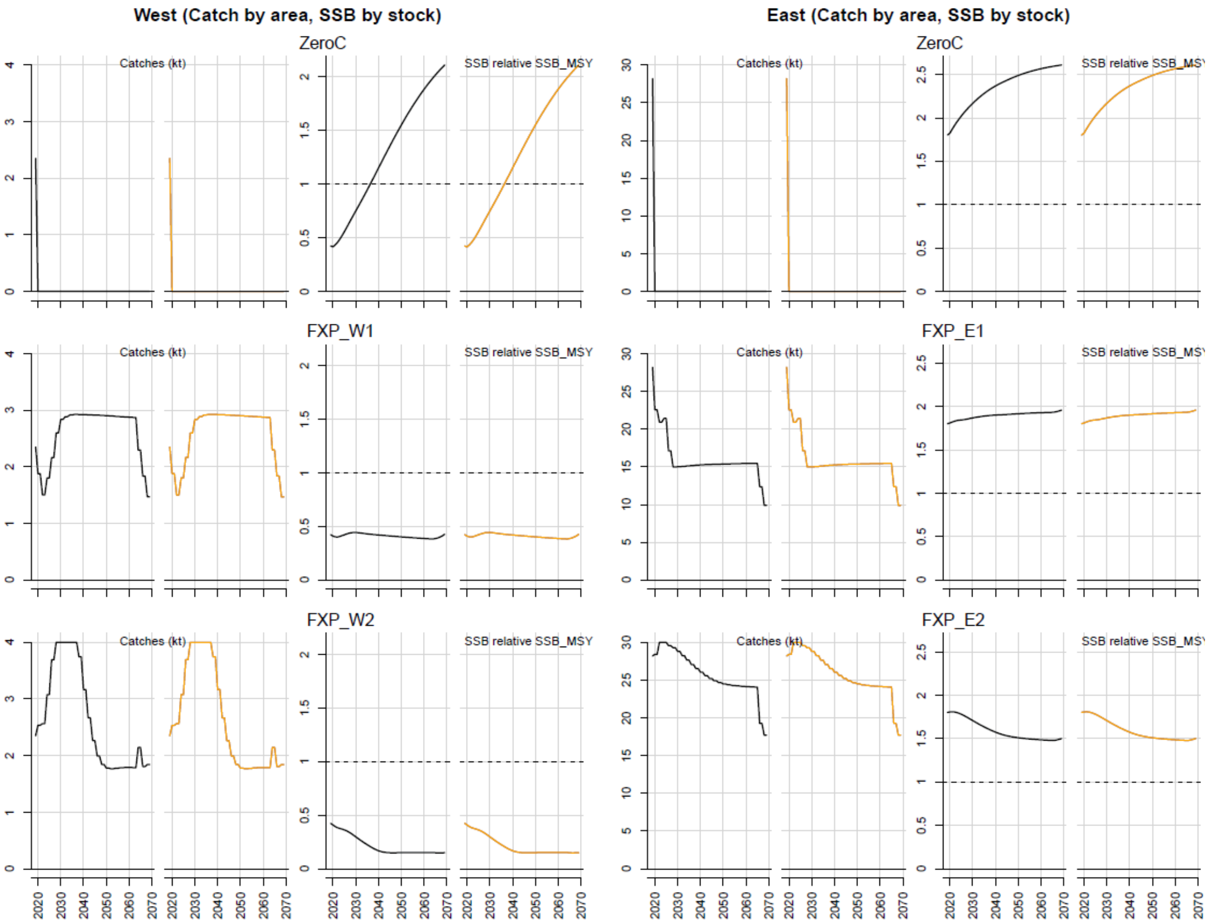

Figure 4b. Deterministic catch and SSB projections for OM14 for zero catch, FXP_1 and FXP_2.

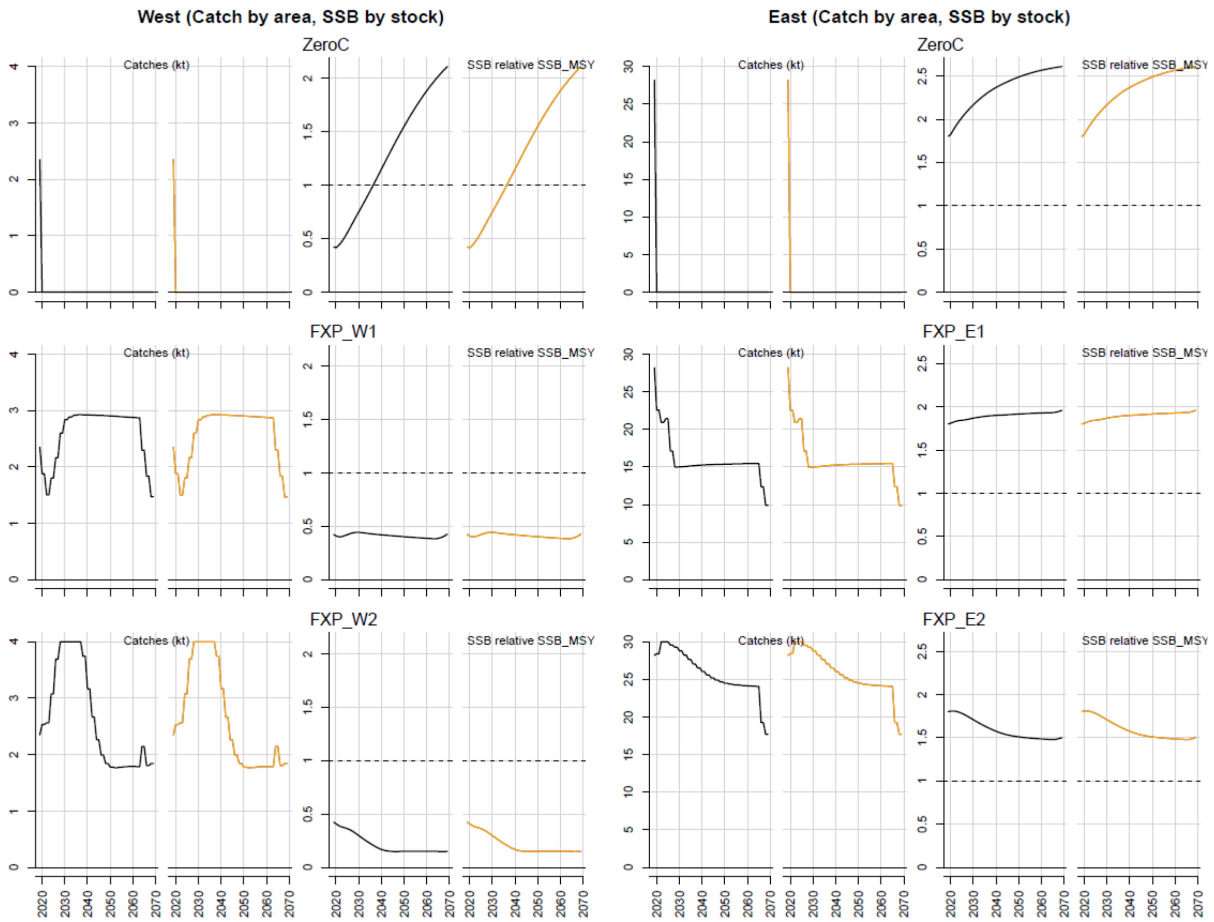

Figure 4c. Deterministic catch and SSB projections for OM15 for zero catch, FXP_1 and FXP_2.

Annex

Deterministic results for the robustness tests

This Annex provides deterministic results for the robustness tests currently available in the Package for the two CMPs (FXP_1 and FXP_2) put forward in SCRS/2019/130, as well as the corresponding results for the "0 catch" scenario.

The factorial design and labelling of the reference set operating models is as follows.

Mixing	**I**		**II**	
Spawn. Frac. / M:	**A**	**B**	**A**	**B**
Recruitment: 1	OM_1	OM_4	OM_7	OM_10
Recruitment: 2	OM_2	OM_5	OM_8	OM_11
Recruitment: 3	OM_3	OM_6	OM_9	OM_12

Robustness test naming and definitions

Table A.1. Priority Robustness Tests

	One factor deviation from OM:		
	OM_4: 1BI	**OM_5: 2BI**	**OM_6: 3BI**
Western Contrast. Increased precision (CV of 15%) of the GOM_LAR_SUV index to create greater contrast in current western stock status	ROM_1	ROM_2	ROM_3
	OM_1: 1AI	**OM_2: 2AI**	
Gulf of Mexico SSB. Prior on higher GOM SSB in quarter 2 and lower GOM SSB in quarter 3	ROM_4	ROM_5	
'Brazilian catches'. Catches in the South Atlantic during the 1950s are reallocated from the West to the East.	ROM_6	ROM_7	
Time varying mixing. Future movement switches from half stock mixing (robustness scenario 1) to 150% stock mixing every three years.	ROM_8	ROM_9	
Persistent change in mixing. Future movement permanently switches from half mixing to 150% mixing after 10 years.	ROM_10	ROM_11	

Table A.2. Other suggested robustness tests. Upweighting refers to a five times increase in the likelihood weighting component ω for a particular data type.

	One factor deviation from OM:	
	OM_1: 1AI	**OM_2: 2AI**
Senescence. An increase in natural mortality rate for older individuals as applied in CCSBT	ROM_12	ROM_13
Upweighting of CPUE indices	ROM_14	ROM_15
Upweighting of 'fishery independent' indices	ROM_16	ROM_17
Upweighting of genetic stock of origin data. 5x likelihood factor on genetics, ignore microchemistry SOO data by increasing imprecision to a logit CV of 500%	ROM_18	ROM_19
Greater influence of microchemistry stock of origin data. 5x likelihood facto on microchemistry data, and ignore genetics SOO data by increasing imprecision to a logit CV of 500%	ROM_20	ROM_21
Greater influence of the length composition data	ROM_22	ROM_23
Greater influence of the historical landings data	ROM_24	ROM_25
Unreported Overages. Future catches in both the West and East are 20% larger than the TAC as a result of IUU fishing (not accounted for by the MP)	ROM_26	ROM_27
Catchability Increases. CPUE-based indices are subject to a 2% annual increase in catchability	ROM_28	ROM_29
Non-linear indices. Hyperstability / hyper depletion in OM fits to data is simulated in projection years for all indices	ROM_30	ROM_31
Probabilistic recruitment shifts. The same recruitment shift as Factor 1 level 3, but with prob of 0.05 for each of the first 20 years of projection	ROM_32	ROM_33
Decreasing catchability. 2% annual decline in the catchability of CPUE-based indices	ROM_34	ROM_35

Table A.3. Deterministic results for Br30 and AvC30 for "0 catch" scenario and for two CMPs: FXP_1 (α=0.5, β=0.5) and for FXP_2 (α=1.0, β=1.0) for those of robustness tests ROM1 to ROM30 that are presently available in the Package. Note that the reason that AvC30 is not zero for the "0 catch" results is that the catches for the first three years of the 30-year projection period are already fixed at the amounts landed or TACs already set and so are included in the average; after those first three years the subsequent projected catches are zero.

	WEST						EAST					
	Br30			AvC30			Br30			AvC30		
	C=0	FXP_1	FXP_2	C=0	FXP_1	FXP_2	C=0	FXP_1	FXP_2	C=0	FXP_1	FXP_2
ROM_1	2.690	1.106	0.820	0.223	3.111	3.638	2.991	2.263	1.956	2.652	21.718	29.546
ROM_2	1.398	0.410	0.149	0.223	2.534	3.204	2.445	1.910	1.527	2.652	17.730	27.640
ROM_3	2.867	1.716	1.423	0.223	3.113	3.638	2.677	1.655	1.305	2.652	22.712	29.546
ROM_4	2.931	2.222	1.975	0.223	2.862	3.624	3.157	2.499	2.091	2.652	19.560	29.546
ROM_5	2.450	2.106	1.919	0.223	2.587	3.615	2.544	2.029	1.643	2.652	17.644	27.839
ROM_6	2.909	2.128	1.870	0.223	2.891	3.625	3.163	2.510	2.105	2.652	19.539	29.546
ROM_7	2.404	1.959	1.727	0.223	2.612	3.616	2.535	2.008	1.616	2.652	17.685	27.842
ROM_8	3.019	2.528	2.342	0.223	2.709	3.622	3.157	2.411	2.411	2.652	21.856	29.546
ROM_9	2.502	2.233	2.065	0.223	2.456	3.615	2.568	2.043	1.675	2.652	18.821	28.967
ROM_10	3.019	2.500	2.296	0.223	2.644	3.621	3.157	2.387	2.112	2.652	22.321	29.546
ROM_11	2.502	2.210	2.020	0.223	2.430	3.614	2.568	2.034	1.668	2.652	19.045	29.354
ROM_12	2.830	2.346	2.124	0.223	2.711	3.624	3.101	2.580	2.175	2.652	18.648	29.218
ROM_13	2.380	2.147	2.013	0.223	2.540	3.619	2.541	2.178	1.878	2.652	17.301	27.549
ROM_14	2.998	2.466	2.140	0.223	2.417	3.569	3.033	2.085	1.631	2.652	21.377	29.546
ROM_15	2.420	1.974	1.628	0.223	2.299	3.562	2.295	1.502	0.971	2.652	17.546	25.858
ROM_16	2.705	1.402	1.090	0.223	3.078	3.633	3.196	2.541	2.185	2.652	20.238	29.546
ROM_18	2.784	1.902	1.683	0.223	3.056	3.618	3.233	2.676	2.345	2.652	19.653	29.546
ROM_19	2.148	1.480	1.191	0.223	2.694	3.608	2.642	2.216	1.892	2.652	17.411	27.773
ROM_20	2.894	1.953	1.631	0.223	2.809	3.621	3.128	2.432	2.023	2.652	19.984	29.546
ROM_21	2.000	1.089	0.774	0.223	2.948	3.621	2.491	1.890	1.465	2.652	18.358	28.315
ROM_22	2.965	2.366	2.162	0.223	2.871	3.630	3.209	2.705	2.371	2.652	19.121	29.546
ROM_23	2.533	2.399	2.323	0.223	2.505	3.616	2.732	2.499	2.310	2.652	16.721	27.173
ROM_24	2.902	2.157	1.913	0.223	2.891	3.625	3.152	2.476	2.079	2.652	19.867	29.546
ROM_25	2.385	1.926	1.691	0.223	2.636	3.616	2.542	2.014	1.622	2.652	17.870	28.118
ROM_26	2.922	2.109	1.901	0.223	2.975	3.627	3.158	2.424	2.092	2.652	21.152	29.546
ROM_27	2.405	1.931	1.713	0.223	2.724	3.618	2.539	1.961	1.551	2.652	18.966	29.546
ROM_28	2.922	2.238	1.916	0.223	2.656	3.621	3.158	2.578	2.140	2.652	17.991	28.576
ROM_29	2.405	2.006	1.750	0.223	2.420	3.613	2.539	2.062	1.691	2.652	16.654	16.342
ROM_30	2.922	2.657	2.455	0.223	1.253	2.032	3.158	2.927	2.822	2.652	10.696	13.927

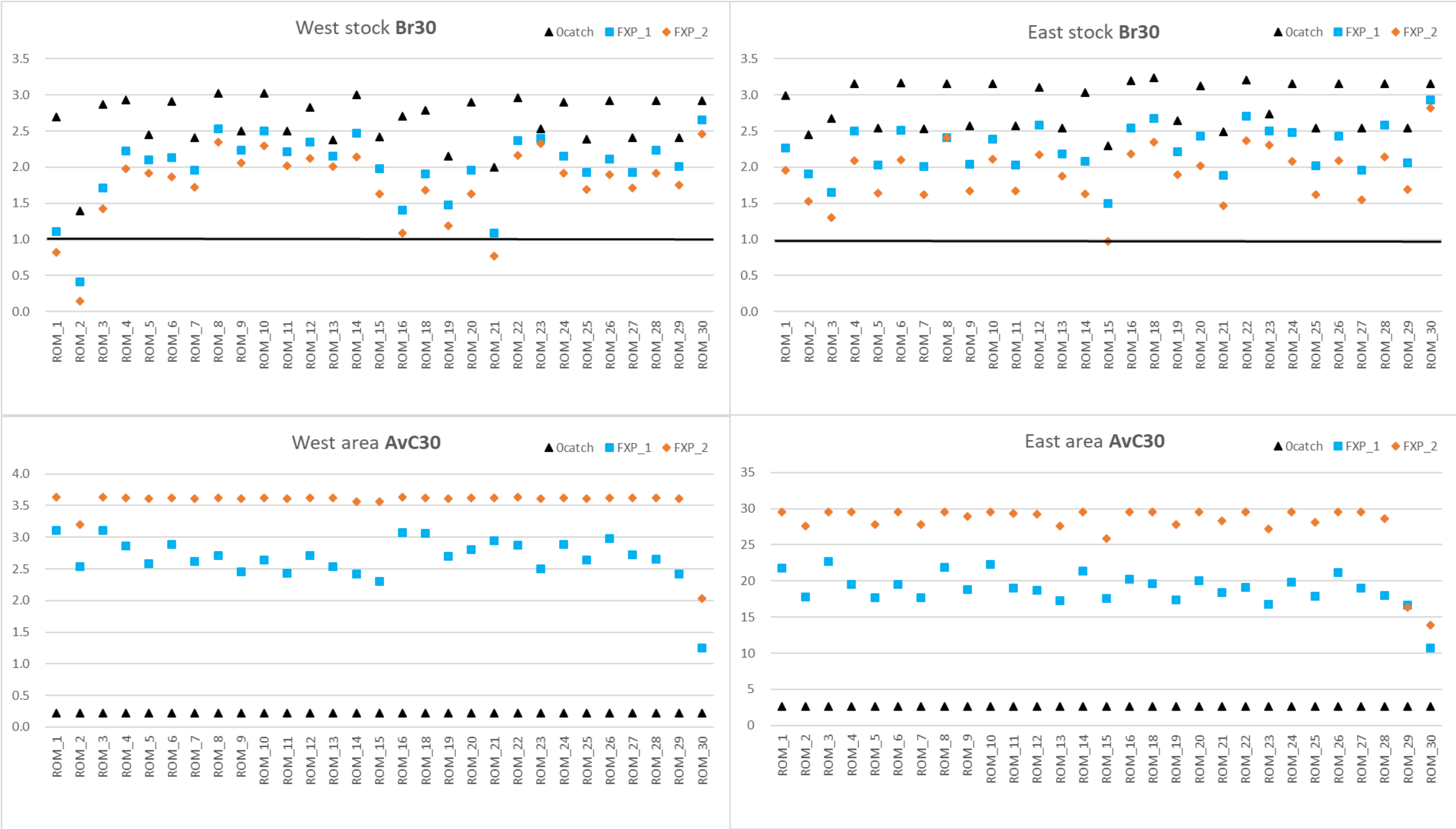

Figure A.1. Deterministic results for Br30 and AvC30 for "0 catch" scenario and for two CMPs: FXP_1 (α=0.5, β=0.5) and for FXP_2 (α=1.0, β=1.0) for those of robustness tests ROM1 to ROM30 that are presently available in the Package. Note that the reason that AvC30 is not zero for the "0 catch" results is that the catches for the first three years of the 30-year projection period are already fixed at the amounts landed or TACs already set and so are included in the average; after those first three years the subsequent projected catches are zero.