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RESULTS FOR INITIAL EXPLORATIONS OF SIMPLE CANDIDATE "FIXED PROPORTION" MPs FOR ATLANTIC BLUEFIN TUNA BASED ON THE OPERATING MODELS PACKAGE CIRCULATED

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SUMMARY

In an initial exploratory exercise, simple fixed proportion MP control rules are applied using composite abundance indices for the East and West areas, where these composites take weighted averages over standardised values of the agreed indices and are then averaged over the last three years for which they would be available. These candidate MPs (CMPs), which also impose a 20% cap on biennial TAC changes, show ready ability to achieve median depletion close to the MSY spawning biomass for each stock within a 30-year projection period for a number of members of the Reference Set of Operating Models (OMs). Two insights from the analyses are first that discussion is needed regarding the most appropriate statistic to use to measure resource depletion in circumstances where some OMs allow for changes in stock recruitment relationships at some time during the projection period considered. The second is that resource depletion can at times be too great for the OM for which the historical abundance of the East stock shows a large increase over recent years. Typical TAC changes are also greater than desirable for adequate stability from an industrial viewpoint. Suggestions are made for further work towards improving MP performances in these respects.

RÉSUMÉ

Dans un exercice exploratoire initial, des règles simples de contrôle de la procédure de gestion (« MP ») à proportions fixes sont appliquées en utilisant des indices d'abondance composite pour les zones Est et Ouest, où ces composites considèrent des moyennes pondérées au lieu de valeurs standardisées des indices convenus, et dont on calcule ensuite la moyenne sur les trois dernières années pour lesquelles ils seraient disponibles. Ces MP concourantes (« CMP »), qui imposent également un plafond de 20% sur les changements de TAC bisannuels, démontrent une capacité d'épuisement médiane proche de la biomasse reproductrice de la PME pour chaque stock dans une période de projection de 30 ans pour un certain nombre de membres du jeu de référence des modèles opérationnels (OM). Les deux idées tirées des analyses indiquent d'abord qu'une discussion est nécessaire sur la statistique la plus appropriée pour mesurer l'épuisement des ressources dans des circonstances où certains OM permettent des changements dans les relations stock-recrutement à un moment donné au cours de la période de projection considérée. La seconde est que l'épuisement des ressources peut parfois être trop important dans l'OM pour lequel l'abondance historique du stock de l'Est montre une forte augmentation au cours des dernières années. Les changements typiques de TAC sont également plus grands que souhaitables pour une stabilité adéquate d'un point de vue industriel. Des suggestions sont faites pour poursuivre les travaux visant à améliorer les performances des MP à cet égard.

RESUMEN

En un ejercicio exploratorio inicial se aplicaron normas fijas de proporción simple de control de MP mediante índices de abundancia compuestos para las zonas oriental y occidental, donde estos compuestos consideran promedios ponderados en vez de valores estandarizados de los índices acordados, calculándose a continuación los promedios para los tres últimos años en los que estarían disponibles. Estos MP candidatos (CMP), que imponen también un tope del 20% a los cambios bienales en el TAC, muestran una capacidad de merma mediana cercana a la biomasa reproductora en RMS para cada stock en un periodo de proyección de 30 años para un número de miembros del conjunto de referencia de modelos operativos (OM). Del análisis se desprenden

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dos ideas, la primera consiste en que es necesario debatir la estadística más apropiada a utilizar para medir el merma del recurso en las circunstancias en las que algunos OM permiten cambios en las relaciones stock-reclutamiento en algún momento durante el periodo de proyección considerado. La segunda es que la merma del recurso puede a veces ser demasiado grande para el OM en el que la abundancia histórica del stock del este muestra un gran incremento en años recientes. Los cambios típicos en el TAC son más que deseables para una estabilidad adecuada desde el punto de vista de la industria. Se sugirió que se debería seguir trabajando para mejorar el desempeño de los MP en este sentido.

KEYWORDS

Atlantic bluefin tuna, Fixed proportion,
Management procedure, Operating model, Resource depletion

Introduction

This document is primarily illustrative in nature, presenting results for some simple Candidate MPs (CMPs) applied to a number of the Reference Set of Operating Models (OMs) (as implemented in the "package" provided by Tom Carruthers). Table 1 gives the specifications of these OMs.

Single composite abundance indices are developed for both the East and West areas, which aggregate over the four and three indices available for these two areas respectively. The CMPs considered essentially set TACs as fixed proportions of these aggregate indices, though subject to a maximum 20% change when TACs for each area are revised every two years.

The longer term intent is to further revise these CMPs to improve their performances in terms of key performance statistics.

Methods

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 (σ^2) shown by that standardised index over the chosen years. The mathematical details are as follows:

J_y is an average index over *n* series (*n*=4 for the East area and *n*=3 for the West area)

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

where

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

[2] These years commence from 2012 (JPN_LL_NEAtl2), 2010 for FR_AER_SUV, 2013 for MED_LAR_SUV, 2011 for MED_AER_SUV and JPN_LL2, 1994 for US_RR_115_144, and 1984 for GOM_LAR_SUV.

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[3]:

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

where the J applies to 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:

$$TAC_{E,y} = \left(\frac{TAC_{E,2018}}{J_{E,2016}}\right) \cdot \alpha \cdot J_{av,y-2}^{E} \quad ^{4} \quad (3a)$$

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:

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

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.

Some experimentation suggested that the choices of α=1.5 and β=1.5 (giving what is termed CMP1.5) provided reasonable performance over the OMs considered, with spawning biomass close to its MSY value after 30 years (the equality of these two control parameter values is co-incidental). To consider also less and more aggressive approaches, CMP1.1 and CMP1.7, corresponding to α=β=1.1 and α=β=1.7 respectively, were also tested.

A key concern arises if the lower 10 %ile of B/B_{MSY} at the end of the 30 year projection period is fairly low. In an effort to ameliorate such behaviour, a threshold value was set for J_{av} for each area, such that below these values α and β drop linearly to zero as J_{av} declines:

$$\text{If } J_{av,y}^{E} < J_{av,thres}^{E},\ TAC_{E,y} = \left(\frac{TAC_{E,2018}}{J_{E,2016}}\right) \cdot \left(\frac{J_{av,y}^{E}}{J_{av,thres}^{E}}\right) \cdot \alpha \cdot J_{av,y}^{E} \quad (4a)$$

[3] For the French and Mediterranean aerial survey, there is no value for 2014 and 2015 respectively. These years were omitted from this averaging where relevant.
[4] The reason that the subscript on J_{av} is y-2 here is that one would set a TAC for year y during year y-1, at which time the most recent abundance indices available would be for year y-2. In implementation for this document, the y-2 was inadvertently set to y. This should not impact results greatly, and certainly negligibly in qualitative terms; an initial check indicates only a slight increase in the PIs of performance statistics. This error will be corrected in following work.

$$\text{If } J^W_{av,y} < J^W_{av,thres},\ TAC_{W,y} = \left(\frac{TAC_{W,2018}}{J_{W,2016}}\right) \cdot \left(\frac{J^W_{av,y}}{J^W_{av,thres}}\right) \cdot \beta \cdot J^W_{av,y} \qquad (4b)$$

where the values used were $J^E_{av,thres} = 0.463$ and $J^W_{av,thres} = 0.405$ (which are slightly less than the values expected at MSY).

This option was implemented allowing in addition for TAC decreases for up to 40% for J_{av} below the threshold J value.

Results

Table 2 lists the values of four key performance statistics (medians and 95% PIs) for the various CMP – OM combinations considered. These four statistics are:

D30 - depletion (SSB in projection year 30 relative to unfished SSB given current recruitment dynamics) for projected year 30,

B/B_{MSY}(%) – SSB in projection year 30 relative to SSB at MSY,

AvC30 - mean annual catch (in '000 t) over the first 30 projected years, and
AAVC(%) - average annual variability in yield over the first 30 projection years.

Table 3 effectively extends **Table 2** to include similar results for CMP1.5Jthres variant.

Figure 1 shows illustrative worm plots for the aggregated abundance index J_{av} (averaged over three years) compared to J for a single year, indicating that the former are smoother over time and less variable.

Figure 2a shows Zeh plots for the CMP-OM combinations considered for the four key performance statistics considered for the East stock or area as appropriate, and Figure 2b does this for the West. Immediately evident, as the intensity of the CMP increases from CMP1.1 to CMP1.7, is the negative correlation between resource abundance and catch related indices. The fact that the lowest lower 2.5%ile for resource depletion in these plots occurs (for the West stock) under OM7 is the reason some further results are shown for OM7 as well as for the "Reference" OM (OM1).

Figures 3a and 3b show worm plots for the East and West for catch and spawning biomass (relative to current levels) for C=0 and the three CMPs considered, first under OM1 and then under OM7. Note that CMP1.5 keeps the spawning biomass close to its present level in median terms under OM1, but that there is a decrease under OM7 for which CMP1.1 better achieves that target.

Figure 4 shows median and lower 10%ile plots over time for catch and spawning biomass (the latter relative to its value at MSY) under CMP1.5 for various OMs. Figure 4a considers OMs for which the future recruitment specifications differ; **Figure 4b** contrasts OMs reflecting different historical abundance trends; and finally **Figure 4c** compares these trends as assumptions about the spawning ogive and natural mortality are changed.

Figure 5 is similar to **Figure 4**, but compares performance for different CMPs for the same OM, rather than for different OMs for the same CMP. **Figure 5a** does this for OM1, and Figure 5b for OM7.

Finally **Figure 6** shows the consequence of changing CMP1.5 to incorporate the "threshold" variation for OM1.

Discussion

The ultimate choice of values for MP control parameters such as α and β, with their associated catch *vs* resource risk trade-offs, is a matter for decision makers. However, if the broad objective adopted is to attain B_{MSY} in median terms after 30 years, the Zeh plots of **Figure 2** suggest choosing an α value for the East slightly greater, and a β value for the West slightly less than 1.5. The worm plots of **Figure 3** suggest that spawning biomass has stabilised within the next 30 years, so that this approach would also achieve F close to F_{MSY} and hence the Kobe plot related objective in median terms[5].

[5] Note that during the ICCAT meeting at which this document was presented, it was discovered that the "package" used was computing MSY-related statistics incorrectly. Hence the associated results reported in this paper should be interpreted only in relative rather than absolute terms.

This initial exploration has deliberately not attempted a comprehensive analysis of or integration over all OMs, or even of all the Reference Set of OMs, but instead through **Figure 4** in particular has sought insight into which of the factors included in the Reference Set has the biggest impact, by varying only one of these factors at a time. Figure 4a shows that the OM3 scenario with "regime" changes (the stock-recruitment relationship changing over time) leads to the biggest impact amongst such scenarios, particularly for the West stock.

Figure 4b shows that the biggest impact across different historical trends is for the scenario (OM7) for which there is a marked increase in the spawning biomass for the East stock over recent years. The CMPs examined show that (at the lower 10%ile, for example) a marked drop in spawning biomass can occur. **Figure 4c** shows that there is little difference in performance across different choices for spawning ogives and for the natural mortality vector.

The results in **Figure 5** are as might be expected: the higher the values of α and β chosen for the CMP, the larger the final spawning biomasses.

Figure 6 (and also Table 3) shows that the "threshold" variant of OM1 does achieve some increase in the lower 10 catches, but the lower %ile for spawning biomass, particularly for the West stock.

In summary

Two issues stand out from the above as meriting further attention. First, discussion is needed about the most appropriate way to report depletion statistics for scenarios when the stock-recruitment function (and hence B_{MSY}) changes over time in the future, to facilitate readier even-handed comparison of such statistics across the different OMs. Possibilities include reporting spawning biomass relative to that for a projected trajectory in the absence of catches, and the "dynamic B0" approach of comparing to the spawning biomass trajectory in the absence of historical as well as future projected catches.

The second concerns the scenario for which the East stock spawning biomass shows a rapid increase over recent years. Resource risk performance is worst for this scenario, and specifically for the West stock. That the West stock is worse affected than the East may seem strange at first sight, but is likely related to the movement of East stock bluefin to the West area, thereby inflating the abundance indices for the West and leading to inappropriately large TACs being recommended there. That this is the main reason needs to be confirmed, but more importantly the "threshold variant" of the FXP-type CMP investigated does not really achieve sufficient improvement in resource depletion performance for this scenario (OM7 – see **Table 3**). Hence other CMP approaches which attempt to achieve improved performance for this scenario require investigation, though the importance of such initiatives depends also on the plausibility to be associated with this scenario relative to the others in the Reference Set of OMs.

Further analyses

The FXP form of CMP investigated here was deliberately kept simple for an initial approach. Further factors/variants still to be investigated include the following.

- Imposing minimum changes on TACs for ease-of-administration reasons, though these are unlikely to have other than a minor impact on key performance statistics.

- Imposing a maximum TAC for each of the East and the West areas. This would seem to have the potential to improve resource depletion for the OM7 scenario, where the current poor performance may be related (in part) to TACs climbing too high under FXP rules with abundance indices in both areas being high in the first few projection years as a result of recent but short-term very high recruitment to the East stock.

- Current TAC variability, with median AAVC values typically in the 5-6% range (bear in mind that this is an *annual* measure – with TAC changes only every second year, those changes will consequently typically be in excess of 10%) are too high for reasonably stable industrial operation. This is a consequence of the high levels of fluctuation in the abundance indices, even when averaged over three years – see **Figure 1**). Averaging over a longer period of years will ameliorate this, but will render management less responsive to very recent changes in resource abundance – this trade-off needs further examination and quantification.

- Other forms of harvest control rule (HCR) to the FXP approach need to be examined, for example “target” based CMPs for which the TAC is adjusted up or down depending on whether the J_{av} index is above or below some chosen target level.

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Table 1. The factors and associated levels which define the reference set of operating models (OMs).

	West	East
Future recruitment		
1	Hockey-stick	83+ B-H with *h* =0.98
2	B-H with *h* estimated	83+ B-H with *h* =0.70
3	Hockey-stick changes to B-H after 10 years B-H after 10 years	83+ B-H with *h* =0.98 changes to 50-82 B-H with *h* =0.98 after 10 years
Abundance		
A	Best estimate	
B	East-West area spawning biomass matches VPA assessment	
C	Recent eastern area SSB increases 3x to match VPA assessment	
Spawning fraction both stocks		**Natural Mortality rate both stocks**
I	Younger	High
II	Younger	Low
III	Older	High
IV	Older	Low

Table 2a. Performance statistics for the **East** stock for biomass and **East** area for catches for a number of combinations of FXP CMPs and OMs. The values are projected median and 95% Probability Intervals. The performance statistics shown are (from top to bottom): D30 - depletion (SSB in projection year 30 relative to unfished SSB given current recruitment dynamics) for projected year 30, B/B_{MSY}(%) – SSB in projection year 30 relative to SSB at MSY, AvC30 - mean annual catch (in ‘000 t) over the first 30 projected years, AAVC(%) - average anuual variability in yield over the first 30 projection years.

				D30			B/BMSY(%)			*AVC30*			AAVC(%)		
OM_CMP	OMSpecification	alpha	beta	median	low	high	median	low	high	median	low	high	median	low	high
OM1_1.1	1AI	1.1	1.1	0.41	0.30	0.57	173	123	231	21.5	18.0	25.2	6.86	5.55	7.88
OM1_1.5		1.5	1.5	0.32	0.21	0.46	136	91	188	25.0	20.4	28.8	6.92	5.93	8.04
OM1_1.7		1.7	1.7	0.29	0.18	0.41	124	79	170	26.0	21.3	30.1	7.07	6.11	8.18
OM2_1.1	2AI	1.1	1.1	0.33	0.22	0.49	137	95	195	19.8	16.4	23.1	6.80	5.40	7.75
OM2_1.5		1.5	1.5	0.23	0.14	0.38	98	60	152	22.3	18.1	26.3	7.10	6.02	8.14
OM2_1.7		1.7	1.7	0.20	0.11	0.33	85	48	133	23.3	18.6	27.3	7.24	6.15	8.57
OM3_1.1	3AI	1.1	1.1	0.42	0.28	0.57	170	133	242	21.5	18.3	25.2	6.85	5.53	7.91
OM3_1.5		1.5	1.5	0.32	0.21	0.46	141	102	203	25.1	21.0	28.4	6.92	5.93	7.93
OM3_1.7		1.7	1.7	0.29	0.18	0.42	130	90	187	26.4	21.7	29.7	6.97	6.19	8.11
OM4_1.1	1BI	1.1	1.1	0.47	0.37	0.61	195	150	250	21.6	18.4	25.1	6.67	5.29	7.69
OM4_1.5		1.5	1.5	0.37	0.27	0.51	156	113	210	25.5	21.8	29.5	6.87	5.76	7.96
OM4_1.7		1.7	1.7	0.34	0.23	0.47	143	99	192	26.9	22.9	30.9	6.84	6.00	8.00
OM7_1.1	1CI	1.1	1.1	0.54	0.41	0.70	224	167	284	20.9	18.3	23.9	6.23	4.94	7.55
OM7_1.5		1.5	1.5	0.45	0.32	0.61	190	133	247	24.8	22.0	28.5	6.55	5.37	7.68
OM7_1.7		1.7	1.7	0.41	0.29	0.57	176	119	232	26.5	23.3	30.3	6.54	5.49	7.59
OM10_1.1	1AII	1.1	1.1	0.31	0.23	0.47	134	98	192	23.5	19.4	28.1	6.82	5.56	7.76
OM10_1.5		1.5	1.5	0.23	0.14	0.36	98	62	148	26.7	21.6	31.6	6.95	5.90	7.98
OM10_1.7		1.7	1.7	0.20	0.12	0.31	86	54	130	27.7	22.5	32.8	7.09	6.09	8.16
OM19_1.1	1AIII	1.1	1.1	0.39	0.29	0.54	167	119	223	21.4	18.0	25.2	6.86	5.62	7.81
OM19_1.5		1.5	1.5	0.30	0.20	0.44	134	89	183	24.9	20.4	28.8	6.98	5.98	8.04
OM19_1.7		1.7	1.7	0.28	0.18	0.40	122	78	167	25.8	21.1	30.1	7.13	6.11	8.26
OM28_1.1	1AIV	1.1	1.1	0.31	0.22	0.45	132	97	188	23.5	19.4	28.3	6.83	5.59	7.72
OM28_1.5		1.5	1.5	0.22	0.14	0.35	98	63	146	26.7	21.6	31.7	6.99	5.87	7.97
OM28_1.7		1.7	1.7	0.19	0.12	0.30	86	54	129	27.7	22.4	32.8	7.14	6.14	8.11

Table 2b. Performance statistics for biomass and catch as in Table 2a except here for the **West** rather than the East stock or area.

				D30			B/BMSY(%)			*AVC30*			AAVC(%)		
Run no.	OMSpecification	alpha	beta	median	low	high	median	low	high	median	low	high	median	low	high
OM1_1.1	1AI	1.1	1.1	0.51	0.35	0.70	102	69	139	2.1	1.9	2.6	6.92	6.15	7.85
OM1_1.5		1.5	1.5	0.41	0.22	0.59	80	44	118	2.5	2.2	3.2	6.78	5.78	7.68
OM1_1.7		1.7	1.7	0.34	0.17	0.54	66	34	109	2.7	2.4	3.4	6.76	5.82	7.85
OM2_1.1	2AI	1.1	1.1	0.53	0.36	0.71	215	147	288	2.1	1.8	2.5	6.90	5.94	7.83
OM2_1.5		1.5	1.5	0.45	0.29	0.62	183	118	253	2.5	2.1	3.1	6.75	5.75	7.58
OM2_1.7		1.7	1.7	0.41	0.25	0.58	169	103	238	2.7	2.3	3.3	6.62	5.64	7.60
OM3_1.1	3AI	1.1	1.1	0.52	0.40	0.71	102	67	146	2.1	1.9	2.6	6.90	6.06	7.82
OM3_1.5		1.5	1.5	0.43	0.32	0.62	86	53	129	2.5	2.2	3.1	6.78	5.94	7.69
OM3_1.7		1.7	1.7	0.40	0.29	0.58	79	47	122	2.7	2.4	3.3	6.71	5.80	7.76
OM4_1.1	1BI	1.1	1.1	0.54	0.42	0.74	108	84	148	2.1	1.8	2.6	6.89	6.07	7.81
OM4_1.5		1.5	1.5	0.46	0.30	0.64	90	60	128	2.5	2.2	3.2	6.94	5.96	7.56
OM4_1.7		1.7	1.7	0.40	0.25	0.59	81	49	119	2.6	2.3	3.4	6.76	6.00	7.52
OM7_1.1	1CI	1.1	1.1	0.59	0.19	0.74	138	31	172	2.0	1.5	2.5	6.64	5.75	7.77
OM7_1.5		1.5	1.5	0.51	0.14	0.65	122	22	153	2.4	1.8	3.0	6.70	5.80	7.71
OM7_1.7		1.7	1.7	0.48	0.12	0.61	115	18	145	2.7	1.9	3.3	6.74	5.72	7.64
OM10_1.1	1AII	1.1	1.1	0.45	0.32	0.59	97	69	130	2.2	2.0	2.7	6.86	6.04	7.81
OM10_1.5		1.5	1.5	0.34	0.19	0.48	74	42	105	2.6	2.3	3.3	6.71	5.77	7.65
OM10_1.7		1.7	1.7	0.28	0.14	0.43	62	31	96	2.8	2.4	3.5	6.73	5.75	7.82
OM19_1.1	1AIII	1.1	1.1	0.48	0.39	0.68	100	80	135	2.1	2.0	2.6	6.92	6.05	7.85
OM19_1.5		1.5	1.5	0.38	0.26	0.56	82	54	115	2.6	2.3	3.1	6.81	5.84	7.57
OM19_1.7		1.7	1.7	0.33	0.20	0.50	69	43	106	2.7	2.5	3.4	6.72	5.77	7.81
OM28_1.1	1AIV	1.1	1.1	0.42	0.34	0.59	96	78	129	2.3	2.1	2.7	6.88	6.04	7.85
OM28_1.5		1.5	1.5	0.32	0.23	0.46	78	53	108	2.7	2.4	3.3	6.77	5.84	7.57
OM28_1.7		1.7	1.7	0.29	0.17	0.42	68	39	98	2.8	2.5	3.5	6.72	5.73	7.70

Table 3. Performance statistics for the (a) East stock for biomass and East area for catches; (b) West stock for biomass and West area for catches for CMP1.5 and CMP1.5Jthres under OM1.

a)East

				D30			B/BMSY(%)			*AVC30*			AAVC(%)		
OM_CMP	OMSpecification	alpha	beta	median	low	high	median	low	high	median	low	high	median	low	high
OM1_1.5	1AI	1.5	1.5	0.32	0.21	0.46	136	91	188	25.0	20.4	28.8	6.92	5.93	8.04
OM1_1.5Jthres		1.5	1.5	0.32	0.22	0.47	140	94	192	24.9	19.6	28.8	7.35	6.16	8.51

b) West

				D30			B/BMSY(%)			*AVC30*			AAVC(%)		
Run no.	OMSpecification	alpha	beta	median	low	high	median	low	high	median	low	high	median	low	high
OM1_1.5	1AI	1.5	1.5	0.41	0.22	0.59	80	44	118	2.5	2.2	3.2	6.78	5.78	7.68
OM1_1.5Jthres		1.5	1.5	0.42	0.24	0.62	81	47	125	2.5	2.1	3.2	7.30	6.01	8.58

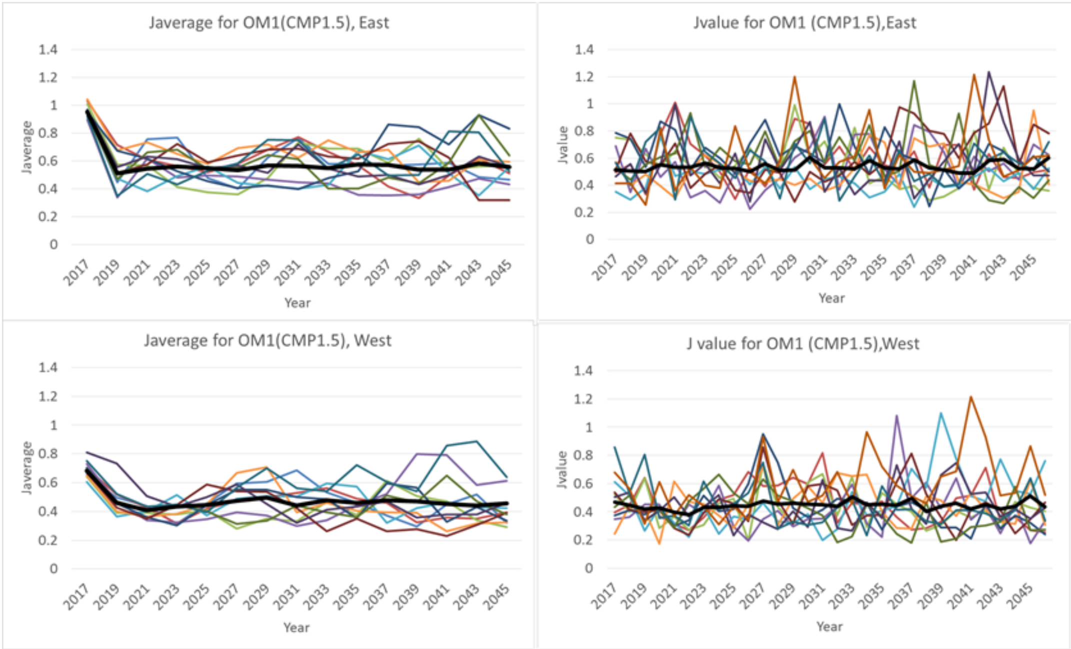

Figure 1. Trajectories of Javerage (J_{av} over three years) and J (for a single year) for projections for 30 years under CMP1.5 for OM1. The solid curves shows the annual medians.

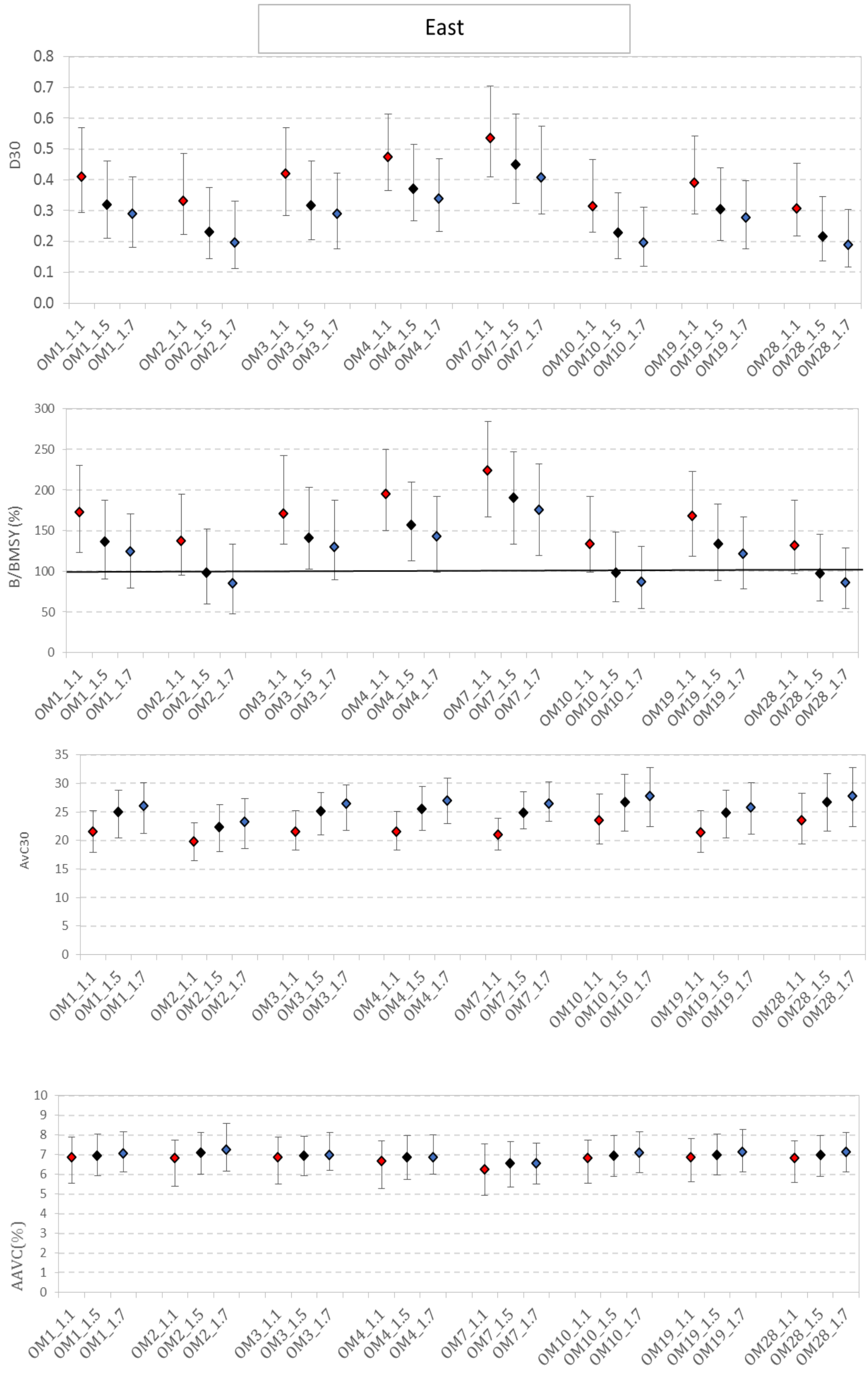

Figure 2a. "Zeh plot"for the **East** stock for biomass and East area for catches for a number of combinations of Fixed Proportion (FXP) CMPs and OMs (e.g. OM1_1.1 denotes CMP1.1 applied to OM1). The symbols show projected median and 95% Probability Intervals. The performance statistics shown are (from top to bottom): D30 - depletion (SSB in projection year 30 relative to unfished SSB given current recruitment dynamics) for projected year 30, B/B_{MSY}(%) – SSB in projection year 30 relative to SSB at MSY, AvC30-mean annual catch (in '000 t) over the first 30 projected years, AAVC (%) - average anuual variability in yield over the first 30 projection years.

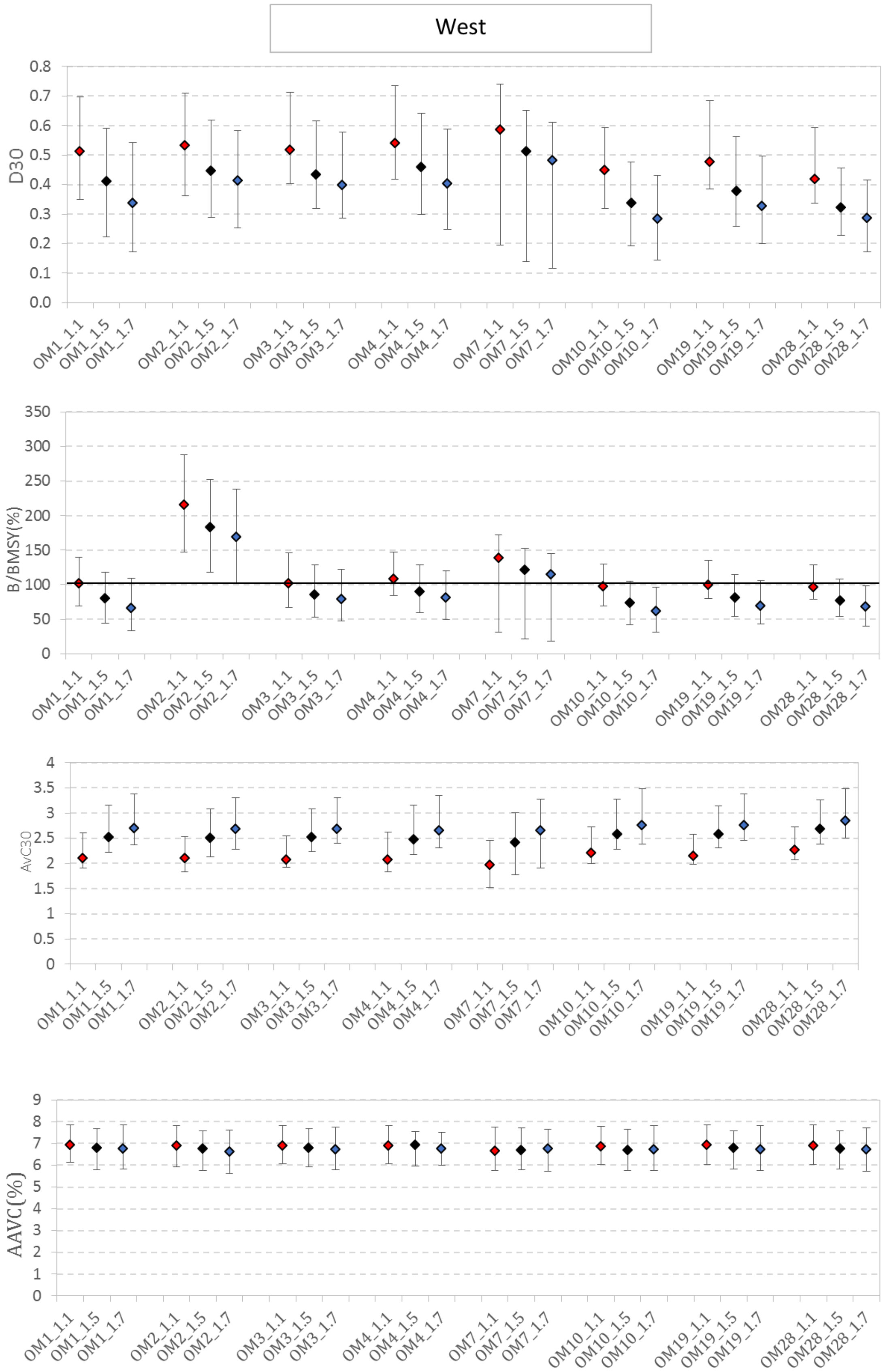

Figure 2b. "Zeh plot"for the **West** stock and area shown as for the East stock and area in **Figure 1a.**

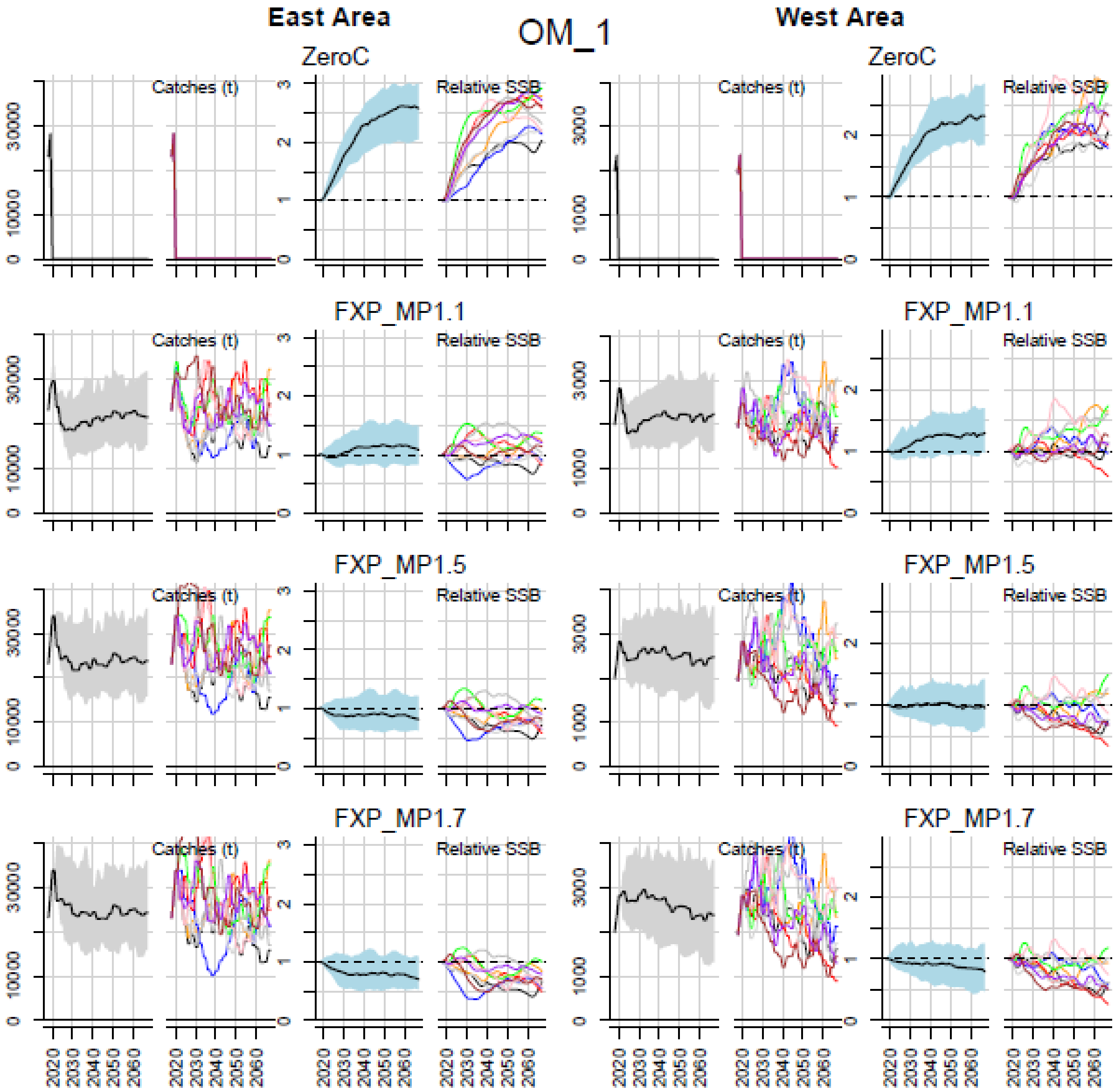

Figure 3a.“Worm“ plots showing individual trajectories as well as the 95% probability envelopes (grey and blue shading) for catch and spawning biomass (relative to current spawning biomass) for the Fixed Proportion CMPs (FXP_MP) for three different sets of tuning parameters (α=β=1.1, 1.5, 1.7) under OM1.

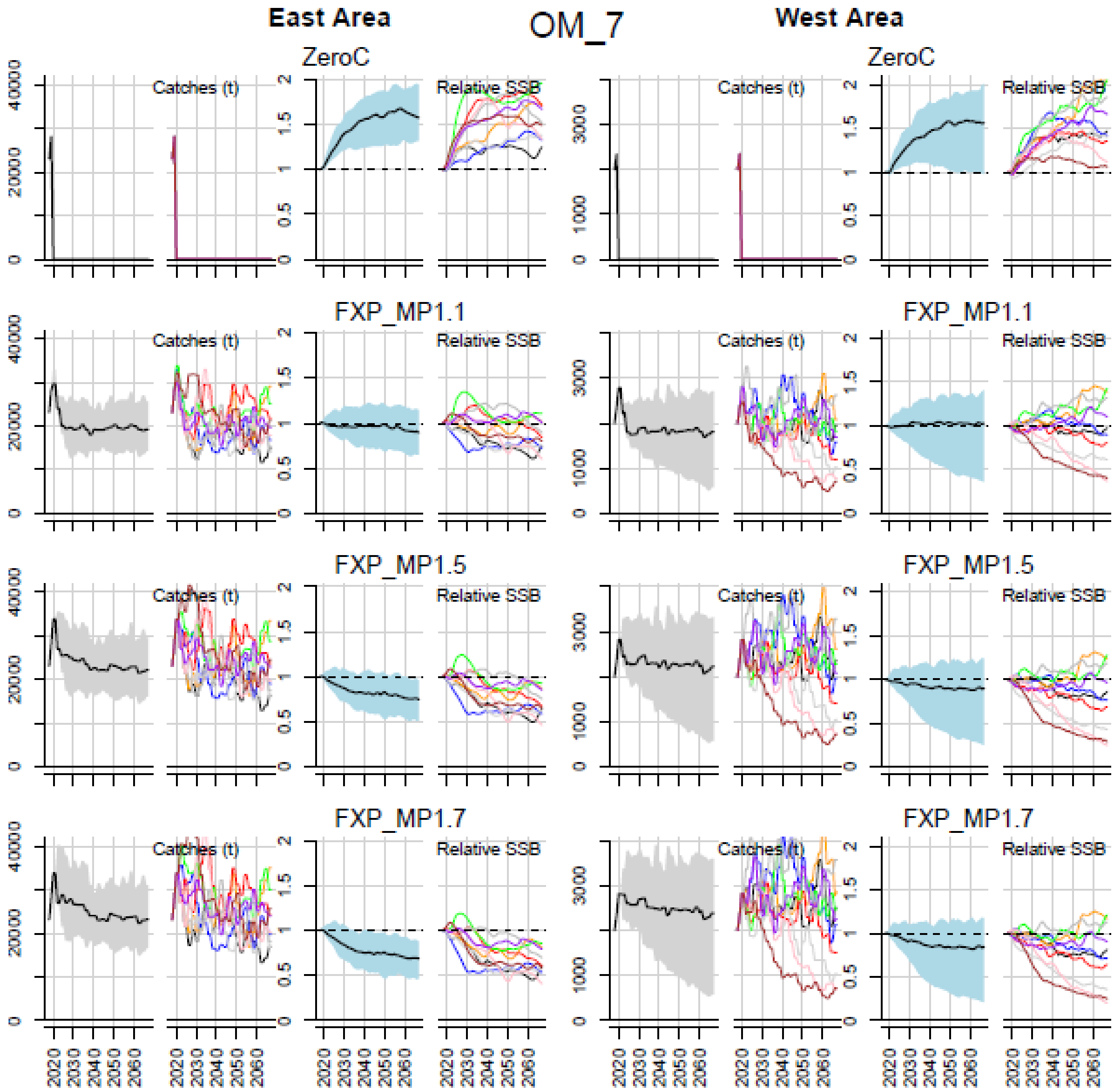

Figure 3b.“Worm“ plots showing individual trajectories as well as the 95% probability envelopes (grey and blue shading) for catch and spawning biomass (relative to current spawning biomass) for the Fixed Proportion CMPs (FXP_MP) for three different sets of tuning parameters (α=β=1.1, 1.5, 1.7) under OM7.

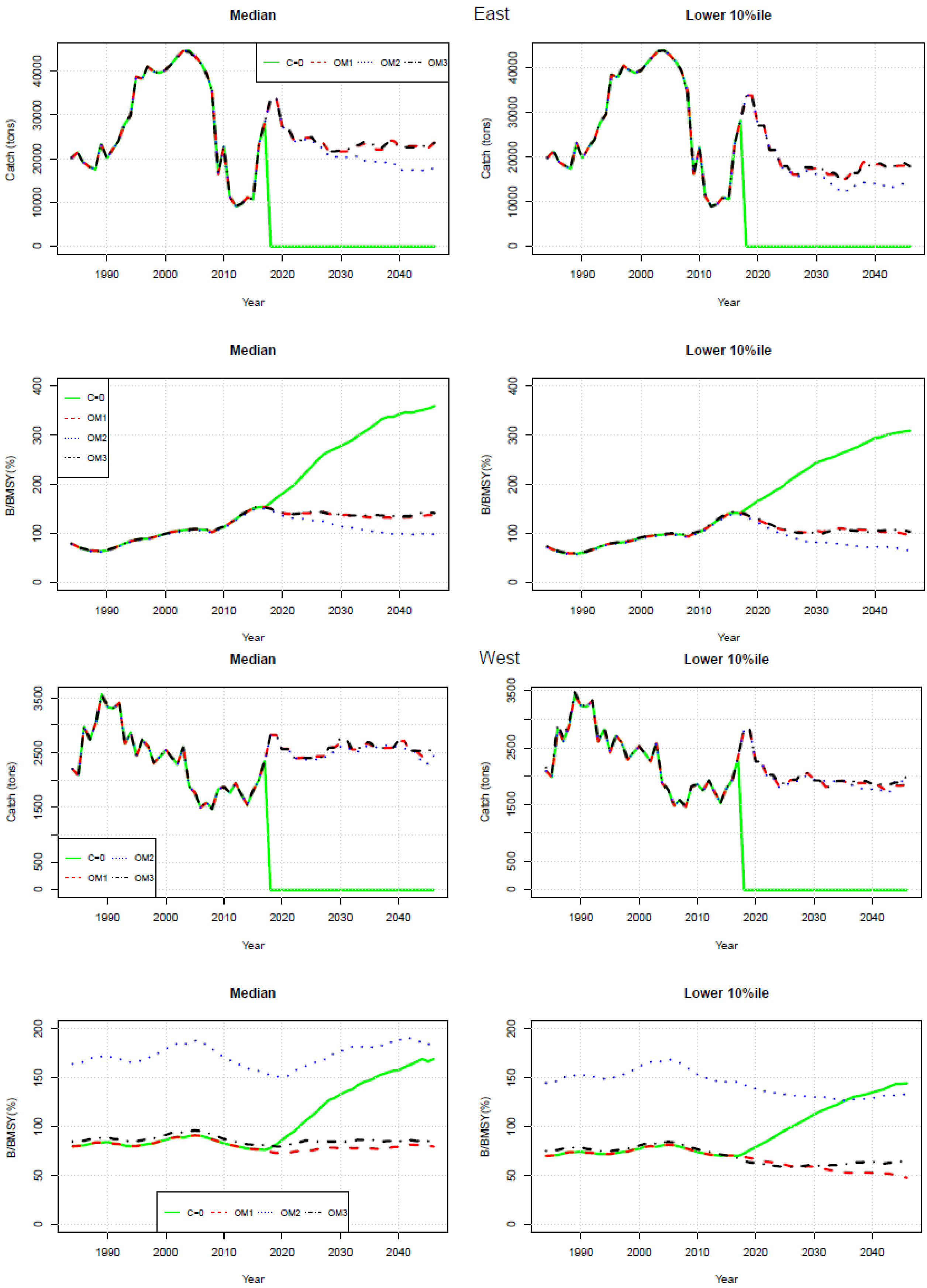

Figure 4a. Projected 30 year median and lower 10%iles for catch and B/B_{MSY} for three OMs: **OM1, OM2, OM3**, as well as for C=0 under OM1, all for CMP1.5.

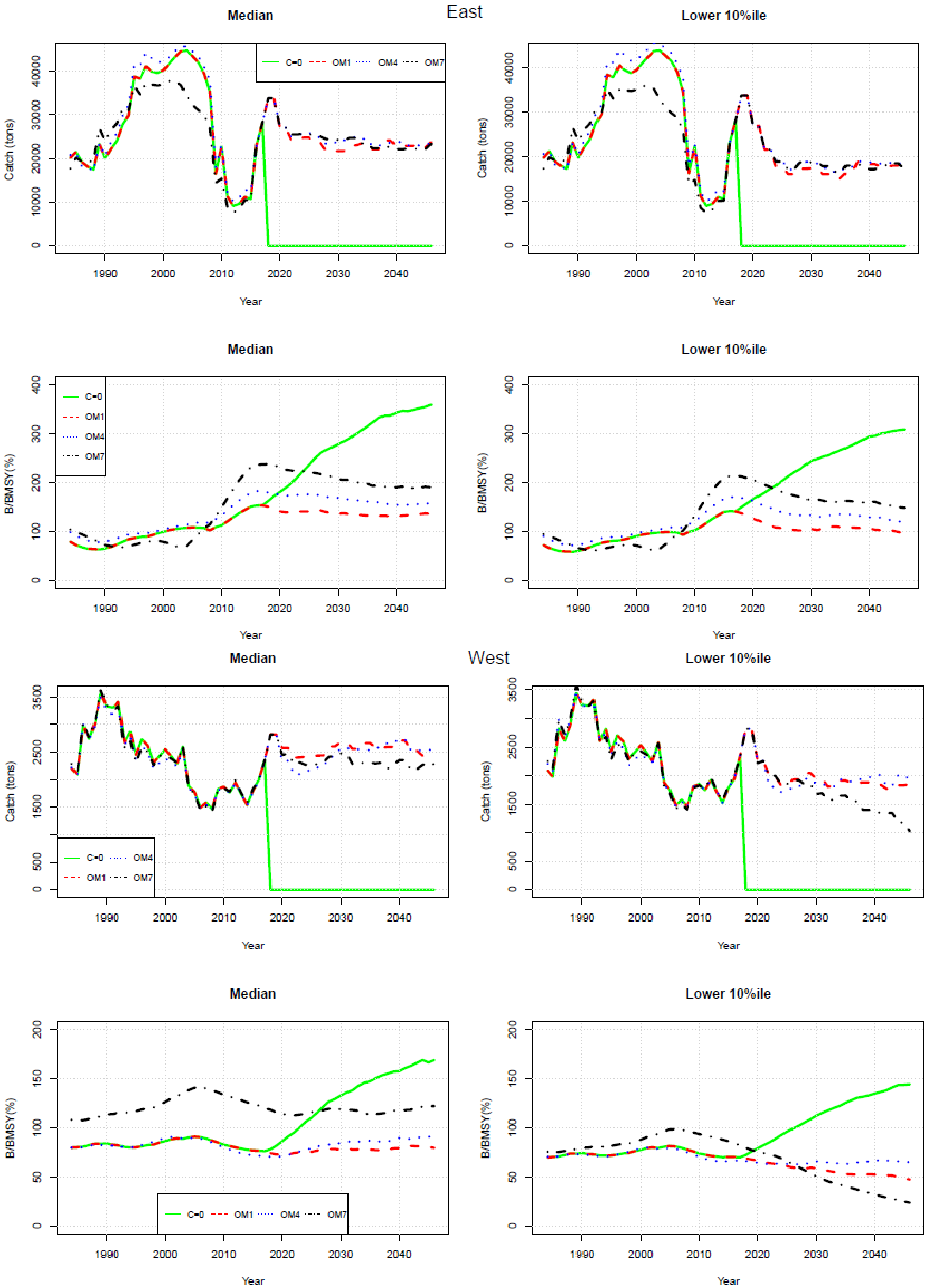

Figure 4b. Projected 30 year median and lower 10%iles for catch and B/B_{MSY} for three OMs: **OM1, OM4, OM7**, as well as for C=0 under OM1, all for CMP1.5.

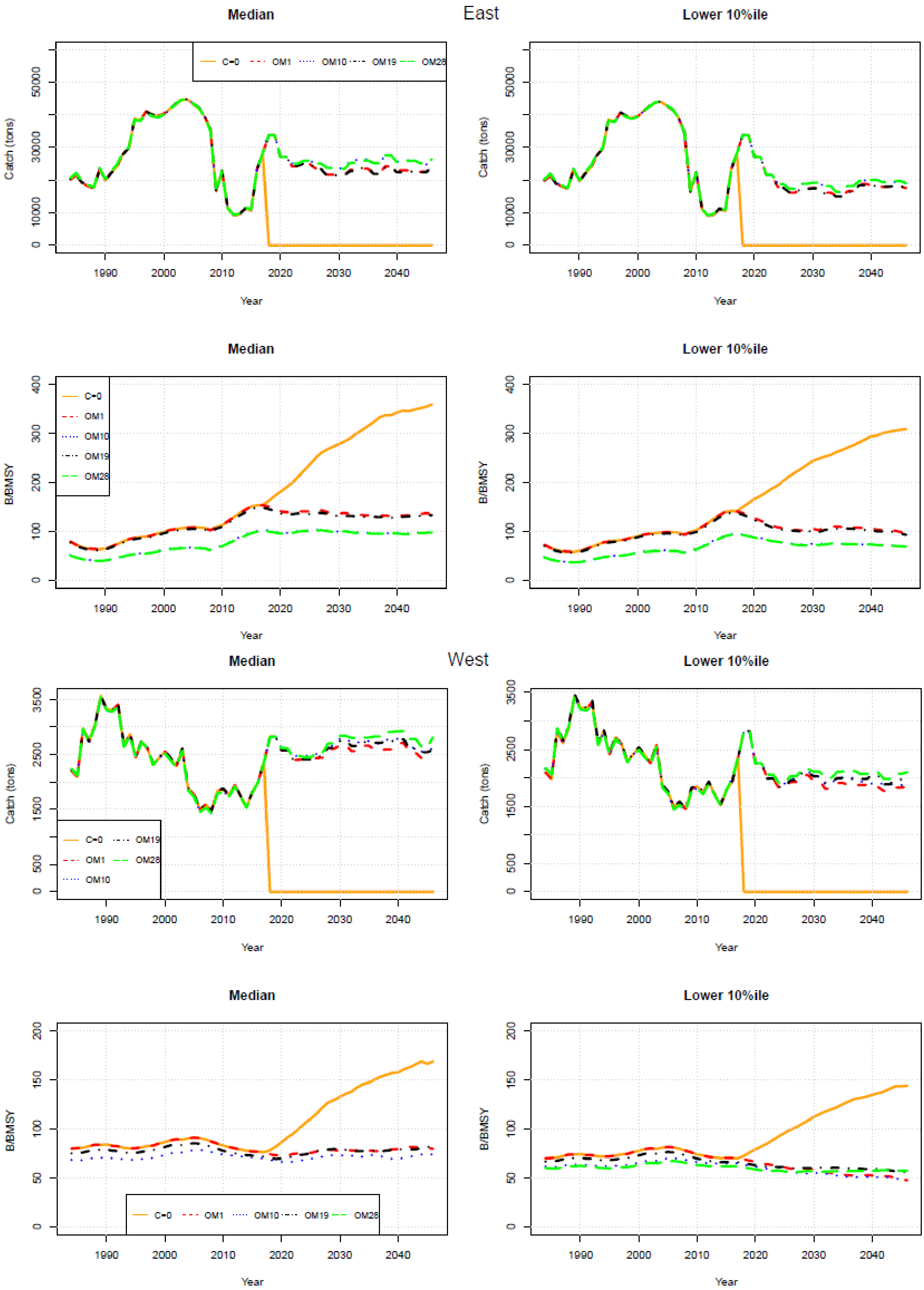

Figure 4c. Projected 30 year median and lower 10%iles for catch and B/B_{MSY} for four OMs: **OM1, OM10, OM19,** and **OM28** as well as for C=0 under OM1, all for CMP1.5.

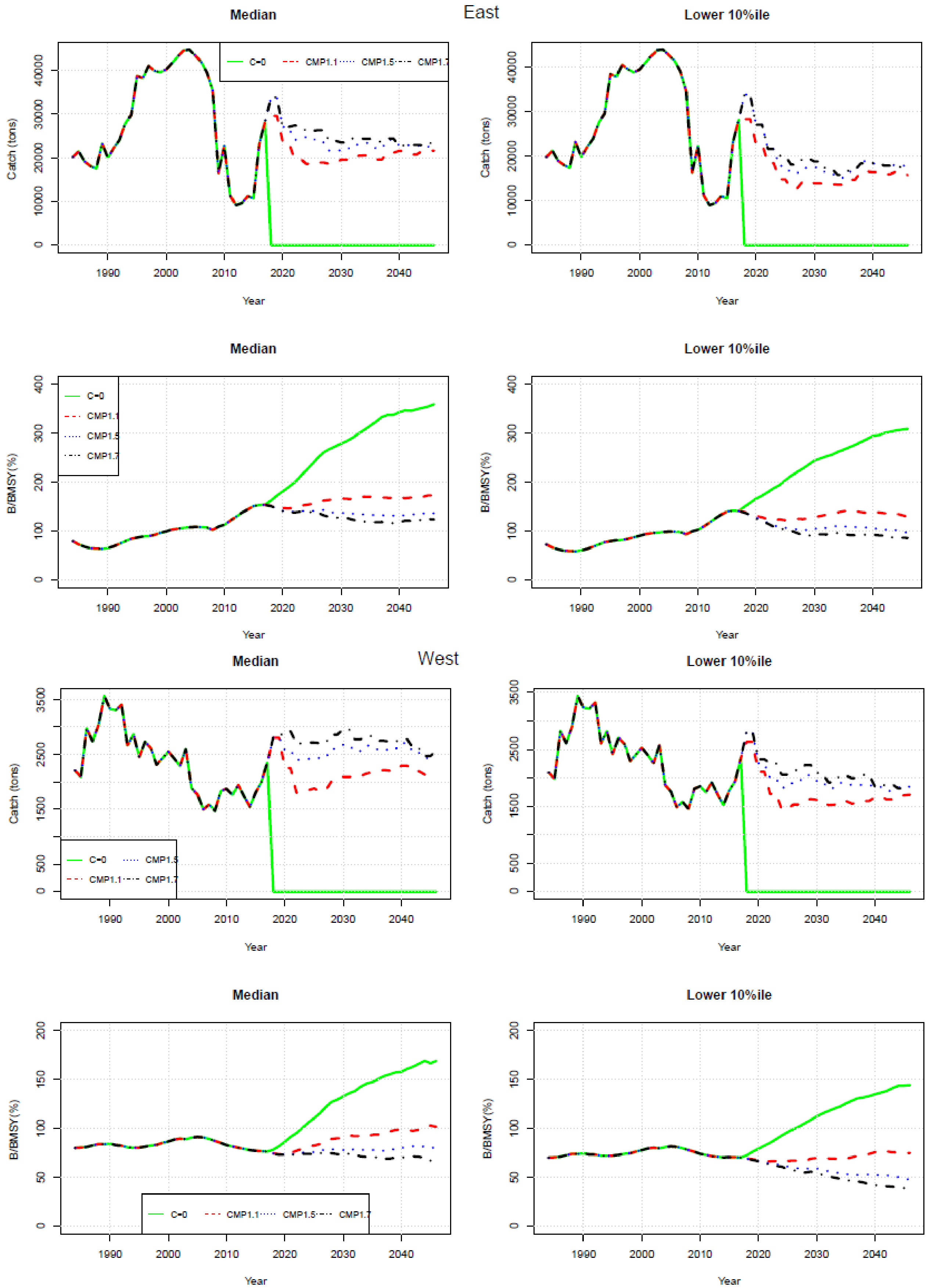

Figure 5a. Projected 30 year median and lower 10%iles for catch and B/B_{MSY} for three CMPs: CMP1.1, CMP1.5 and CMP1.7 as well as for C=0 under **OM1**.

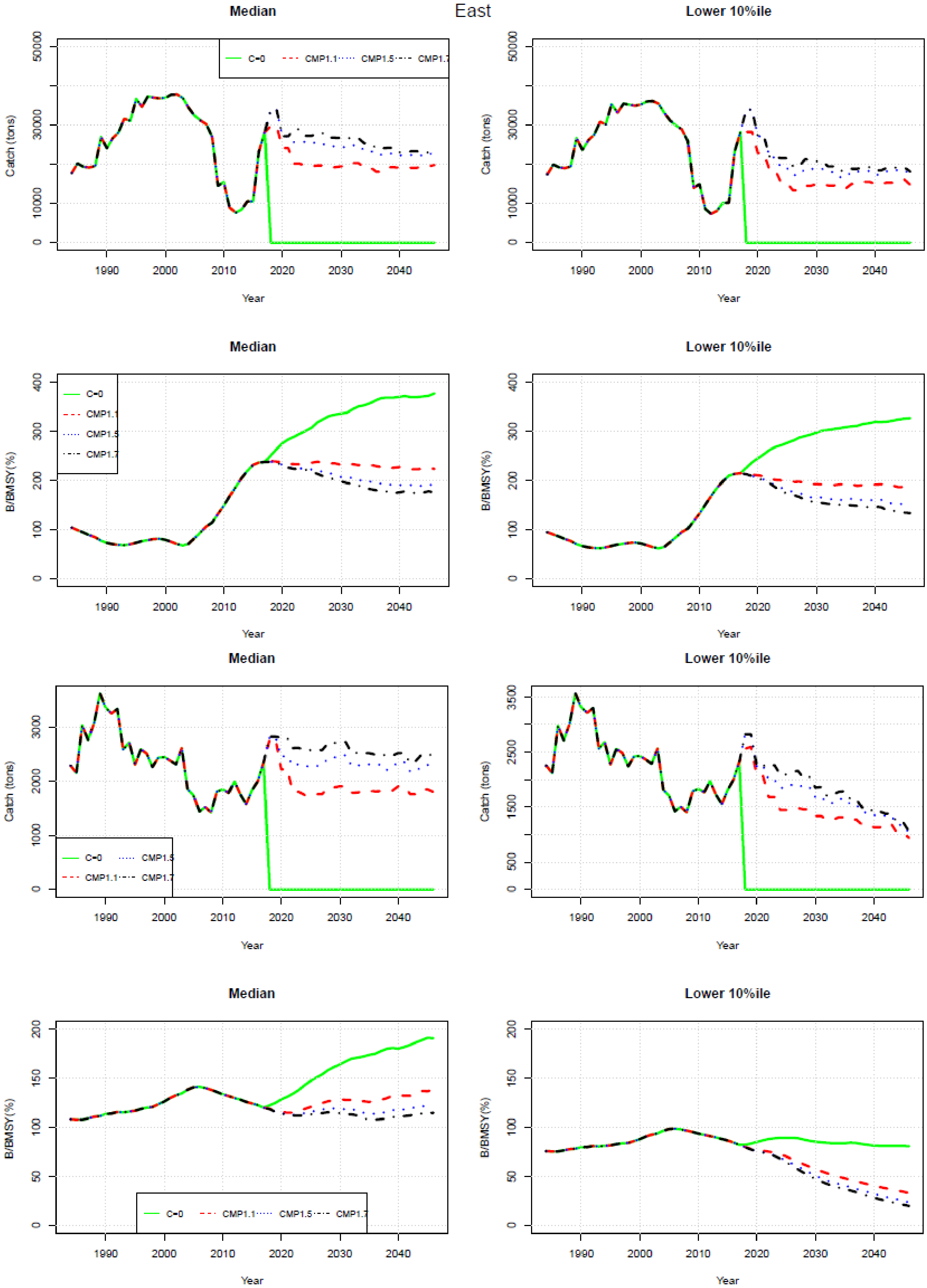

Figure 5b. Projected 30 year median and lower 10%iles for catch and B/B_{MSY} for three CMPs: CMP1.1, CMP1.5 and CMP1.7 as well as for C=0 for **OM7**.

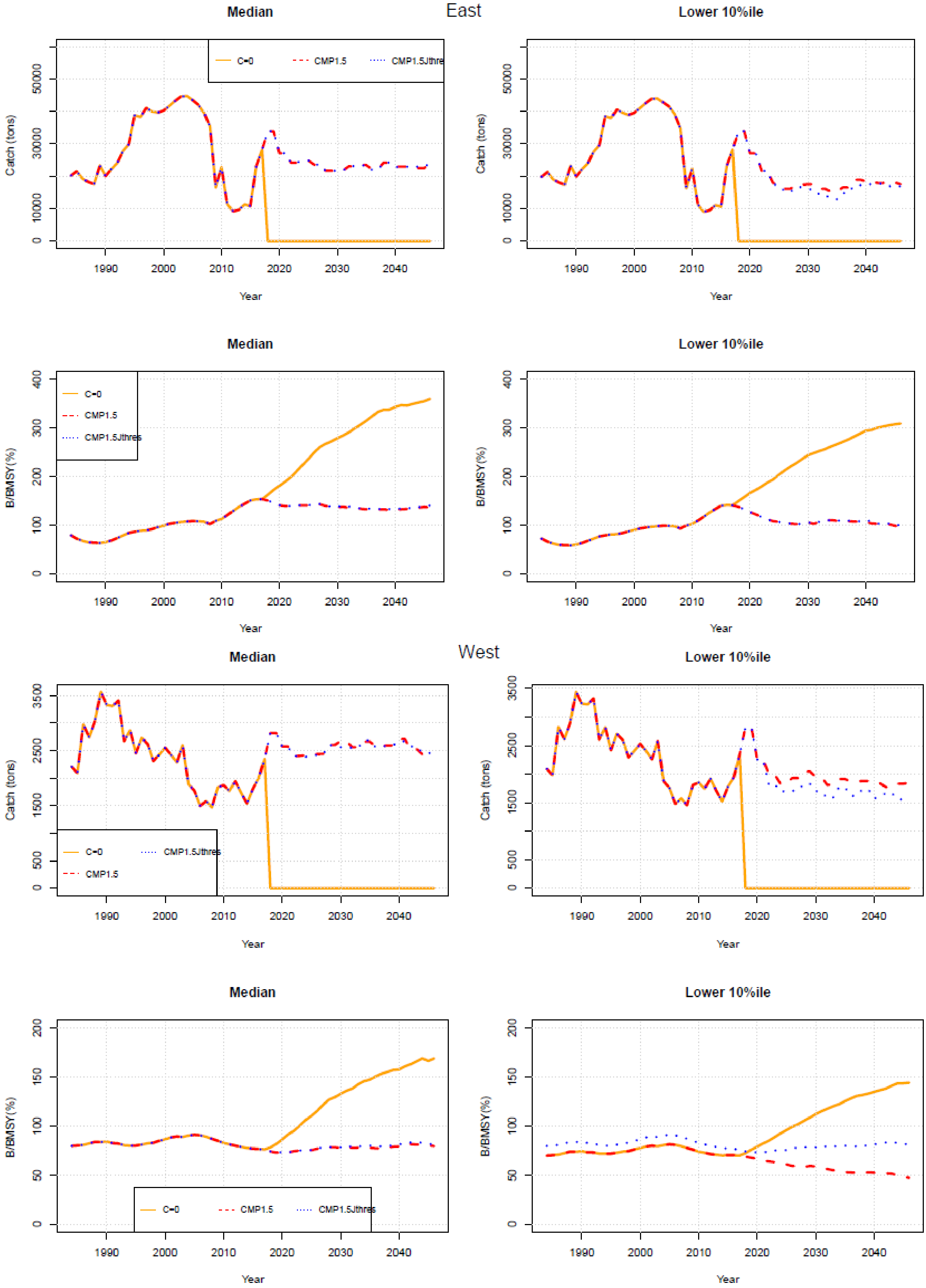

Figure 6. Projected 30 year median and lower 10%iles for catch and B/B_{MSY} for two CMPs: CMP1.5 and CMP1.5Jthres as well as for C=0 under OM1.