PERFORMANCE OF EXAMPLE MANAGEMENT PROCEDURES FOR ATLANTIC BLUEFIN TUNA

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SUMMARY

Two example management procedures are described that calculate total allowable catches using relative abundance indices[3]. The management procedures are tested in the ABT-MSE framework and evaluated according to various performance statistics. Trade-offs among performance metrics and between the two stocks are also characterized.

RÉSUMÉ

Deux procédures de gestion sont décrites à titre d'exemple, lesquelles calculent les prises totales admissibles à l'aide d'indices d'abondance relative[4]. Les procédures de gestion sont testées dans le cadre de l'ABT-MSE et évaluées selon différentes statistiques de performances. Les avantages et les inconvénients entre les mesures des performances et entre les deux stocks sont également caractérisés.

RESUMEN

Se describen dos ejemplos de procedimientos de ordenación para calcular el total admisible de capturas utilizando índices de abundancia relativa[5]. Los procedimientos de ordenación se probaron en un marco ABT-MSE y fueron evaluados en función de varias estadísticas de desempeño. También se describen las ventajas e inconvenientes en función de las diferentes mediciones del desempeño y para los dos stocks.

KEYWORDS

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

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[3] The development of the MSE for North Atlantic bluefin tuna remains an ongoing process at this time. This document is therefore not final, but relates to the extent of development of the work immediately prior to the September 2017 bluefin session which preceded the ICCAT SCRS meeting.
[4] Le développement de la MSE pour le thon rouge de l'Atlantique Nord reste à ce stade un processus en cours. Ce document n'est donc pas définitif, mais se rapporte à l'ampleur du développement des travaux immédiatement avant la session sur le thon rouge de septembre 2017 qui a précédé la réunion du SCRS de l'ICCAT.
[5] En este momento prosigue el proceso de desarrollo de la MSE para el atún rojo del Atlántico norte. Por tanto, este documento no es final, sino que está relacionado con la medida de desarrollo de este trabajo inmediatamente antes de la sesión de atún rojo de septiembre de 2017, que precedió a la reunión del SCRS de ICCAT.

1   Introduction

In this paper two example management procedures (MPs) are described that modify Total Annual Catches (TACs) according to indices of relative abundance. The MPs are tested using the ABT-MSE package alongside four constant catch MPs. Readers are directed to supporting SCRS papers for a full description of the operating models (Carruthers *et al.,* 2016a, Carruthers and Butterworth, in press a), the data used in conditioning (Carruthers *et al.,* 2016b, GBYP 2017) and the software package (Carruthers and Butterworth, in press b). Additionally there are number of peer-reviewed papers that describe the MP approach to fisheries management (e.g. Punt and Butterworth 1999, Cochrane *et al.* 1998, Punt *et al.* 2015).

2   Methods

Two example management procedures are tested for the reference case (RC) operating model (the central OM from the RS (OM #1) that uses the best model estimates of abundance for both stocks, high natural mortality rate and low age at maturity (Carruthers and Butterworth in press a). The first, EMP1 is a very simple index target MP that makes incremental adjustments to the TAC depending on the proximity of recent index observations to a target index level. The second MP, EMP2 originates from Rademeyer and Butterworth (2016), and in addition to proximity to a target level accounts for changes in the slope of indices (whether there is a positive or negative trend). Both of these MPs are empirical; they calculate TACs directly from abundance indices.

Example Management Procedure 1

EMP1 is a very simple index target MP. For each year y, that the TAC is calculated, three inputs are required: the previous TAC recommendation, a mean abundance index J_{y-1} over the most recent five years $J_{y-1} = \frac{1}{5}\sum_{y-5}^{y-1} I_y$ and a target level for that index J_{targ}.

The MP either decreases the TAC by 10%, keeps the TAC the same, or increases the TAC by 10% depending on the ratio of the mean index J_{y-1} to the target index J_{targ}:

$$J_{ratio,y-1} = \frac{J_{y-1}}{J_{targ}} \tag{1}$$

$$TAC_y = TAC_{y-1} \cdot \begin{cases} 0.90 & J_{ratio,y-1} < 0.6 \\ 1 & 0.6 < J_{ratio,y-1} < 1.4 \\ 1.1 & J_{ratio,y-1} > 1.4 \end{cases} \tag{2}$$

Example Management Procedure 2

EMP2 is somewhat more complex and provides TAC adjustments accounting for both the ratio of the current index to the target index J_{ratio}, and also for its longer-term trend s.

$$TAC_y = TAC_{y-1}\left[1 + \lambda_{up/down}s_{y-1} + \rho_{up/down}\left(J_{ratio,y-1} - 1\right)\right] \tag{3}$$

where

s_{y-1} is the slope of a log-linear regression of the index against year over the last six years (y-6 to y-1);

$\lambda_{up/down}$, $\rho_{up/down}$ are control parameters that determine the sensitivity of TAC adjustments.

Similarly to EMP1 (where only TAC changes of +/- 10% are permitted), EMP2 constrains the maximum inter-annual change in the TAC to 15% (both up and down).

A list of the EMP1 and EMP2 control parameter values used can be found in **Table 1**.

Indices and control parameters

For these examples, the Japanese Longline index for the North East Atlantic (JPLL_NEAtl2) was used for setting TACs for the eastern area, while the Gulf of Mexico Larval Survey (GOM_LAR_SUV) was used for setting TACs in the west. Mean values for these indices over the last 5 years were approximately 6 for the Japanese Longline index and 0.6 for the Gulf of Mexico Larval index.

Values were chosen for the target index levels and up/down control parameters to attempt to achieve an appropriate trade-off amongst performance statistics for conflicting objectives (such as high catches and low risk of unintended resource depletion).

Other 'management procedures' for performance comparison

Four other management procedures were evaluated to frame the performance of the example management procedures. These included four constant catch MPs that specified zero catches (ZeroC), or 50%, 100% and 150% of current catches (CurC50, CurC100, CurC150, respectively); these current catches are 13 500 t for the eastern area and 2 000 t for the west.

Performance measures / statistics

A total of 13 performance statistics were defined (**Table 2**, see CMG 2017) that evaluate MPs according to expected magnitude of catches (C10, C20, C30), stock depletion relative to unfished (D10, D20, D30, LD), stock depletion relative to a zero catch scenario (DNC, LDNC), fishing rate and status relative to MSY reference points (POF, POS, PGK) and variability in catches (AAVC). These performance statistics are consistent with MSE applications elsewhere and intended to encompass a range of stakeholder interests.

3   **Results**

The MPs were tested using the reference case operating model (OM#1), which simulates two resilient populations in relatively optimistic states (e.g. high natural mortality rate, low age at maturity, high current spawning biomass relative to unfished). Similarly to other operating models, recent recruitments are estimated to be relatively strong, which leads to stock biomass increases in early projection years for the majority of the simulations (**Figure 1**).

With respect to certain performance metrics relating to conservation (see **Figures 1** and **2**), the performances of all MPs were both comparable and satisfactory. For example, all MPs provided close to a 100% probability of being in the green Kobe zone (PGK, both underfishing and underfished status) after year 30 of the projection (Figure 3).

Other performance statistics such as the lowest level of stock depletion (LD) varied substantially among the MPs and were generally traded-off with short-term and long-term catches (C10, C30) (**Figures 2** and **3**).

For the most part, MPs that performed well in the East also performed similarly well in the West (**Figure 4**) meaning that if these were the only candidates Western performance would not be traded-off against Eastern performance. However this pattern may not be maintained as greater complexity is introduced to the MPs to be considered in the future

Static constant catch MPs (e.g. 150% of the current TAC, CurC150) performed reasonably well compared with the example MPs, EMP1 and EMP2. However again this is a pattern that may not continue once the other Reference Set and robustness tests are introduced.

4   **Discussion**

The purpose of this document is to introduce MP design and demonstrate example MPs. MSE processes are strengthened by comparative testing of multiple MPs developed by a number of different scientists. EMP1 and EMP2 are deliberately simple – they are intended only to be illustrative of the process, and their results shown here should not be over-interpreted. They could easily be improved by modification or the tuning of control parameters.

In general dynamic MPs that react to current data regarding relative abundance can be expected to comprehensively outperform static MPs such as 150% of current TAC (CurC150) (Carruthers *et al.* 2014, Harford and Carruthers 2017). The relative strength of static MPs in this preliminary analysis indicates that future MP development will lead to substantial performance gains over the example MPs presented in this paper.

It is important to appreciate that other operating models that include more conservative assumptions about stock status and productivity may be a harder test of MPs and offer a different view of their relative performance.

A follow up paper (Carruthers and Butterworth, in press b) provides a description of the R package for MP testing (ABT-MSE) and a full worked example of how to code EMP1 and EMP2 into the package and produce the results tables and figures of this paper.

5   Acknowledgements

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Table 1. Control parameters for Example Management Procedures 1 and 2 (EMP1, EMP2).

Control parameter	Value
λ_{up}	0.05
λ_{down}	0.15
ρ_{up}	0.05
ρ_{down}	0.15
J_{targ} -JPLL_NEAtl2 (East MP)	4.8
J_{targ} - GOM_LAR_SUV (West MP)	0.66

Table 2. Performance measures / statistics used to evaluate the performance of management procedures.

Performance Measure	Abbreviation
a) Annual average catch for the first, second and third 10-year period of MP application. Catch statistics are calculated for east and west management areas rather than stocks.	C10, C20, C30
b) Spawning biomass depletion calculated relative to the deterministic equilibrium in the absence of catches for the recruitment function that applies after 10, 20 and 30 years of MP application.	D10, D20, D30
c) The lowest spawning biomass depletion over the 30 years for which the MP is applied calculated relative to the deterministic equilibrium in the absence of catches for the recruitment function that applies after 30 years.	LD
d) Spawning biomass depletion after 30 years, but calculated relative to the trajectory that would have occurred had no catches been taken over the full period for which MP application is being considered.	DNC
e) The lowest spawning biomass depletion over the 30 years for which the MP is applied, but calculated relative to the zero catch trajectory specified in d).	LDNC
f) Kobe indicators: Probability of Overfishing (F>FMSY), Probability overfished state (B < BMSY), Probability green Kobe (F<FMSY and B>BMSY) over 30 projected years	POF, POS, PGK
g) Average annual variation in catches defined by: $$AAVC = \frac{1}{30} \sum_{y=2017}^{2046} \left| C_y - C_{y-1} \right| \Big/ C_{y-1}$$ Catch statistics are calculated for east and west management areas rather than stocks.	AAVC

Table 3. Performance statistics for the 6 MPs for the East and West stocks (see **Table 2** for definition of performance statistics). Catch statistics (C10, C20 and C30) are reported in units of thousand metric tonnes. Probability statistics such as probability of overfishing (POF), probability of overfished status (POS), probability of green Kobe zone (PGK) at the end of the projection period are reported as percentages, as is the inter-annual variability in catches (AAVC). Catch statistics (C10, C20, C30, AAVC) are reported by East and West Management area rather than stock.

| Management procedure	Performance measures / statistics (means)												
East stock	**C10**	**C20**	**C30**	**D10**	**D20**	**D30**	**LD**	**DNC**	**LDNC**	**POF**	**POS**	**PGK**	**AAVC**
ZeroC-ZeroC	0	0	0	0.45	0.674	0.821	0.322	1	1	0	0	100	1.703
CurC50-CurC50	5.897	5.897	5.897	0.42	0.595	0.71	0.316	0.85	0.844	0	0	100	0
CurC100-CurC100	11.79	11.79	11.79	0.39	0.515	0.593	0.31	0.689	0.679	0	0	100	0
CurC150-CurC150	17.69	17.69	17.69	0.36	0.434	0.471	0.3	0.508	0.495	0	0.002	99.91	0
EMP1e-EMP1w	12.28	15.25	20.61	0.389	0.501	0.53	0.233	0.276	0.276	0	0	100	2.238
EMP2e-EMP2w	12.09	13.74	17.32	0.389	0.507	0.557	0.298	0.438	0.438	0	0	100	1.652
West stock	**C10**	**C20**	**C30**	**D10**	**D20**	**D30**	**LD**	**DNC**	**LDNC**	**POF**	**POS**	**PGK**	**AAVC**
ZeroC-ZeroC	0	0	0	0.515	1.093	1.081	0.377	1	1	0	0	100	1.703
CurC50-CurC50	1.812	1.814	1.814	0.463	0.927	0.876	0.349	0.779	0.771	0	0	100	0.013
CurC100-CurC100	3.419	3.598	3.584	0.419	0.772	0.681	0.318	0.56	0.548	0	0	100	0.27
CurC150-CurC150	4.831	5.023	4.949	0.378	0.627	0.501	0.257	0.344	0.333	0	0.004	99.82	0.335
EMP1e-EMP1w	3.372	3.792	4.462	0.419	0.762	0.628	0.215	0.24	0.239	0	0	100	1.699
EMP2e-EMP2w	3.25	3.434	3.851	0.421	0.776	0.666	0.286	0.384	0.381	0	0	100	1.177
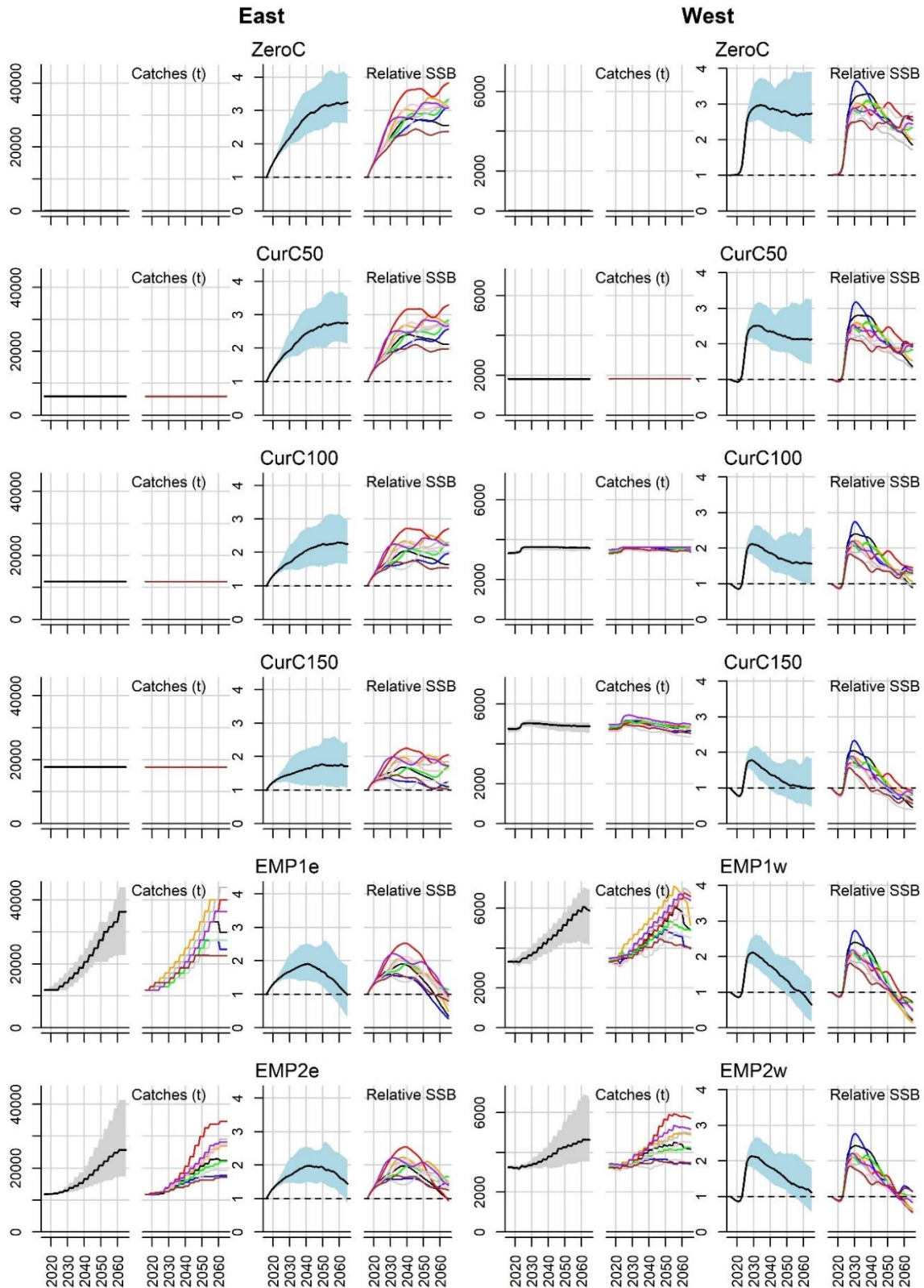
Figure 1. Catch and SSB trajectories for 6 MP pairs (98 simulations, OM #1). Each pair of MPs operates on the existing western and eastern areas. The result plotted here are for the West and East stocks. Each row is an MP pair. For catches East and West refer to the management areas, where SSBs are reported for the East and West stocks. Relative SSB is spawning biomass in the projections divided by SSB in 2016. For both catch and SSB the median estimate of all simulation is a solid curve with the grey shaded region representing the 5th and 95th percentiles. Colored lines represent 10 individual simulations (worm plots). CurC represents current catch MPs. CurC50, CurC100 and CurC150 are 50%, 100% and 150% of current catches.
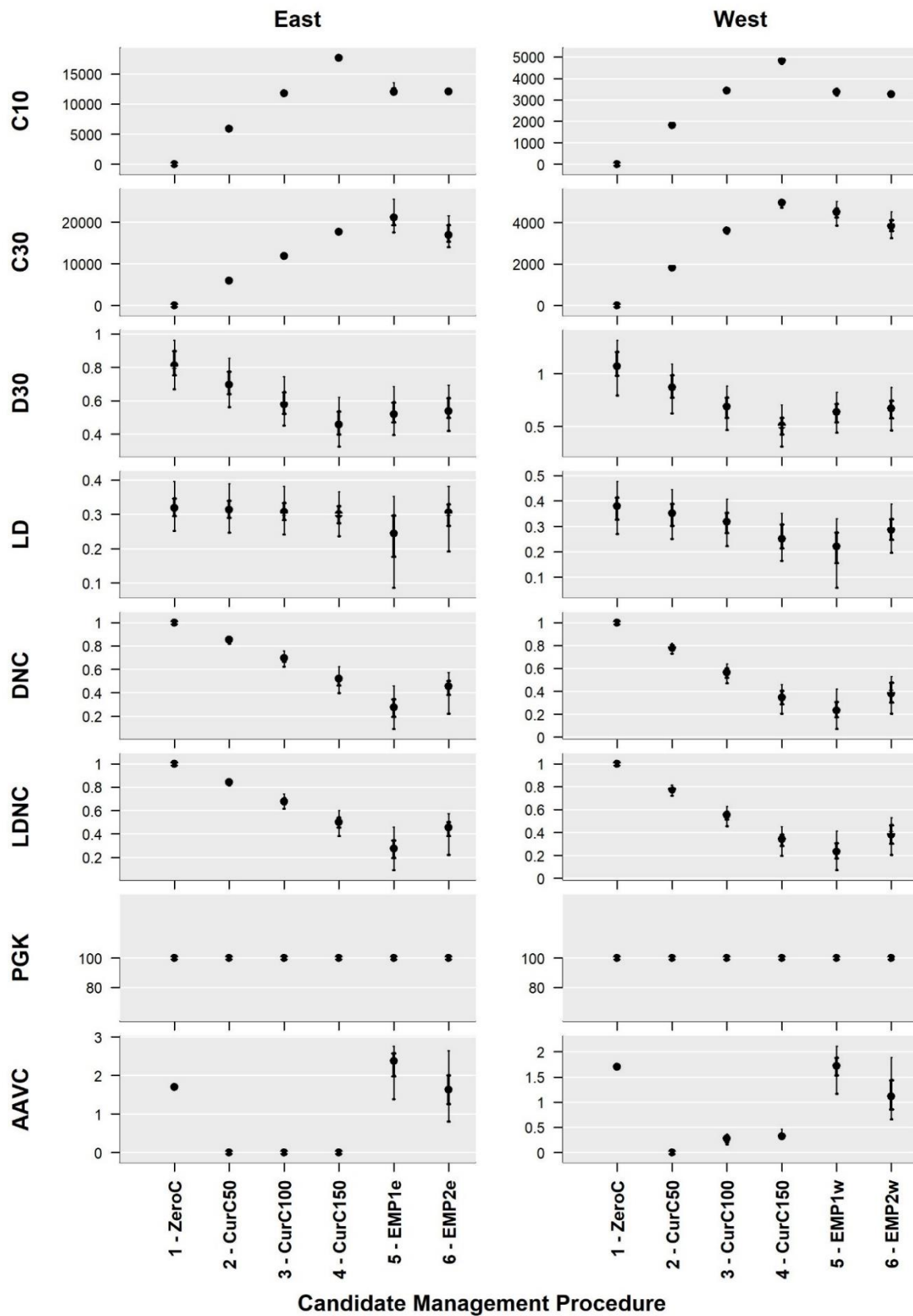
Figure 2. Performances of the 6 example management procedures. Points represent medians (n=96), bold bars are 50% probability intervals and thin bars are 90% probability intervals. Mean catches over the first 10 years and 30 years of the projections (C10, C30) are in units of tonnes. AAVC and probabilities such as PGK are expressed as percentages. For catch statistics C10, C30 and AAVC, east and west refer to management area rather than stock.
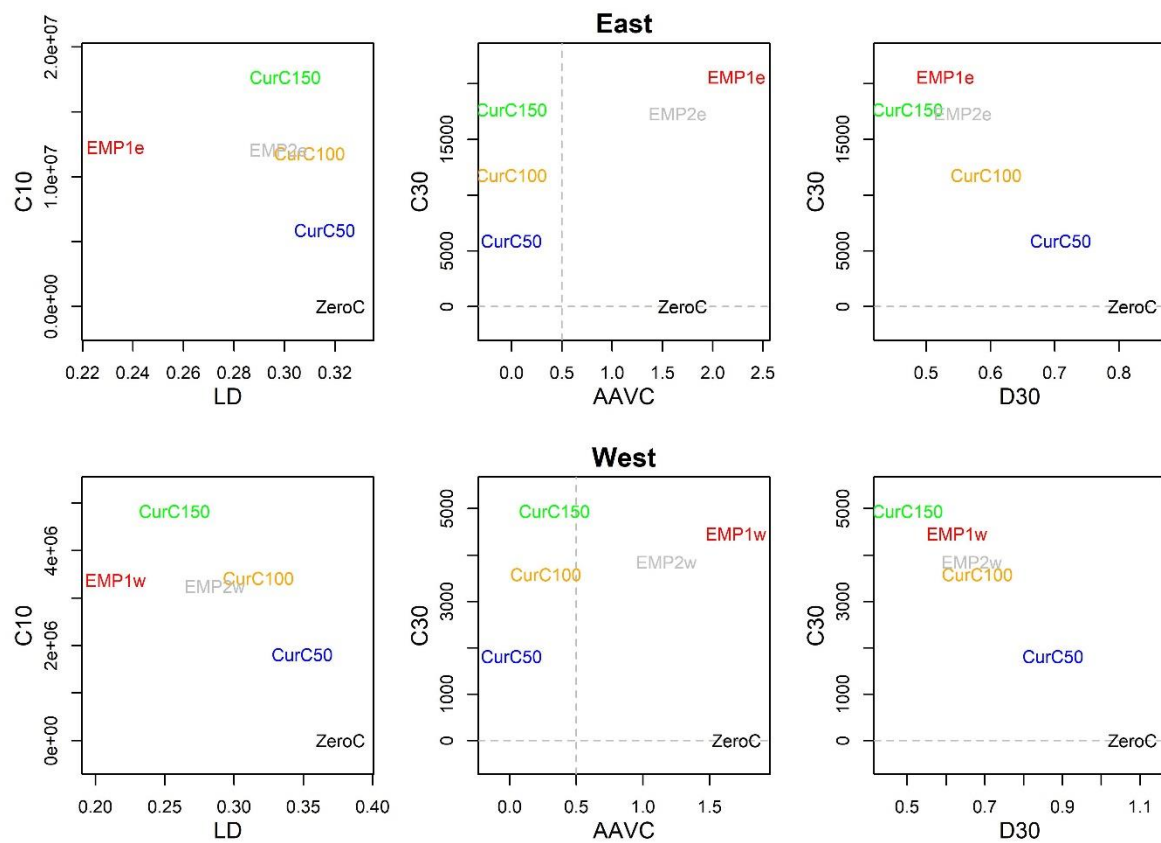
Figure 3. Trade-off among some performance metrics for the East and West stocks.
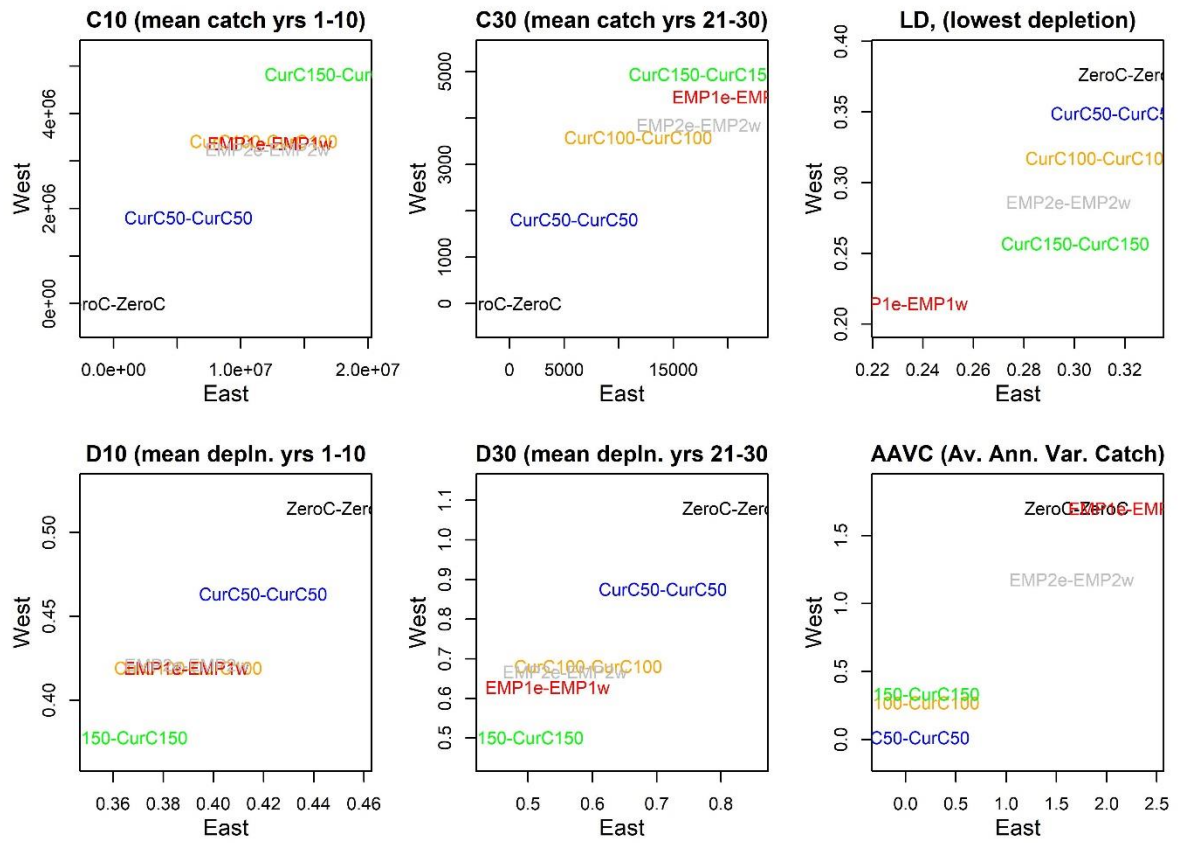
Figure 4. Performance metrics trade-off among the East and West stocks.