IOTC Bigeye Tuna Management Procedure Evaluation Update June 2019[1]

Management Procedure Evaluation Status

- Management Procedure (MP) evaluation is being pursued in the strict sense (i.e. as in the International Whaling Commission and Commission for the Conservation of Southern Bluefin Tuna), in which the data to be input to the MP, the analysis, and the Harvest Control Rule (HCR) are all defined in advance and simulation-tested together.
- The bigeye reference set Operating Model (simulator) is being iteratively developed in line with IOTC technical working party requests (WPTT and WPM). The latest iteration was recommended by the informal MSE Task Force (steering committee), but has not yet been endorsed by the formal working parties or Scientific Committee.
- Several generic MPs have been evaluated for each of the tuning objectives requested by the TCMP-02 (2018). A small subset is presented here to illustrate typical performance.
- The main feedback priority for the TCMP-03 is to refine management objectives and MP tuning targets.
- Scientific and technical support funding ends in Dec 2019.

Bigeye MP Development Guidance from TCMP-02 (2018)

The tuning objective refers to a single key management objective that the MPs can achieve precisely (e.g. achieving SB ≥ SB_{MSY} with a 50% probability by 2024). The tuning objective commonly relates to a desirable biomass (in terms of the risk of exceeding reference points and/or a rebuilding timeframe), and has a very strong influence on the obtainable yield (because biomass risk and attainable catch are closely related). Tuning ensures that candidate MPs are identical with respect to this high priority objective, making it easier to select among MPs on the basis of performance with respect to secondary management objectives (e.g. yield and catch stability). Ideally the Commission will have narrowed down the tuning objectives to 1 or 2 before MP selection. This will allow MP developers to focus MP development. TCMP-02 (2018) defined 3 bigeye tuning objectives for this iteration:

B1: Pr(Kobe green zone 2030:2034) = 0.5. The stock status is in the Kobe green quadrant over the period 2030-2034 exactly 50% of the time (averaged over all simulations).

B2: Pr(Kobe green zone 2030:2034) = 0.6. The stock status is in the Kobe green quadrant over the period 2030-2034 exactly 60% of the time (averaged over all simulations).

B3: Pr(Kobe green zone 2030:2034) = 0.7. The stock status is in the Kobe green quadrant over the period 2030-2034 exactly 70% of the time (averaged over all simulations).

TCMP-02 (2018) further recognized the desirability of other MP constraints:

- Total Allowable Catch (TAC) to be set every 3 years (and held constant between settings)
- A maximum of 15% change to the TAC (increase or decrease) relative to the previous TAC

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Management Procedures Labels

The first character of the candidate MP name designates the MP class, and the next two characters indicate the tuning criterion, e.g. **DB1: data-based MP (lower panel below) tuned to achieve B1 (defined above)**. Usually the tuning objective is more important than the MP type in determining management performance.

"M" class (model-based) MPs

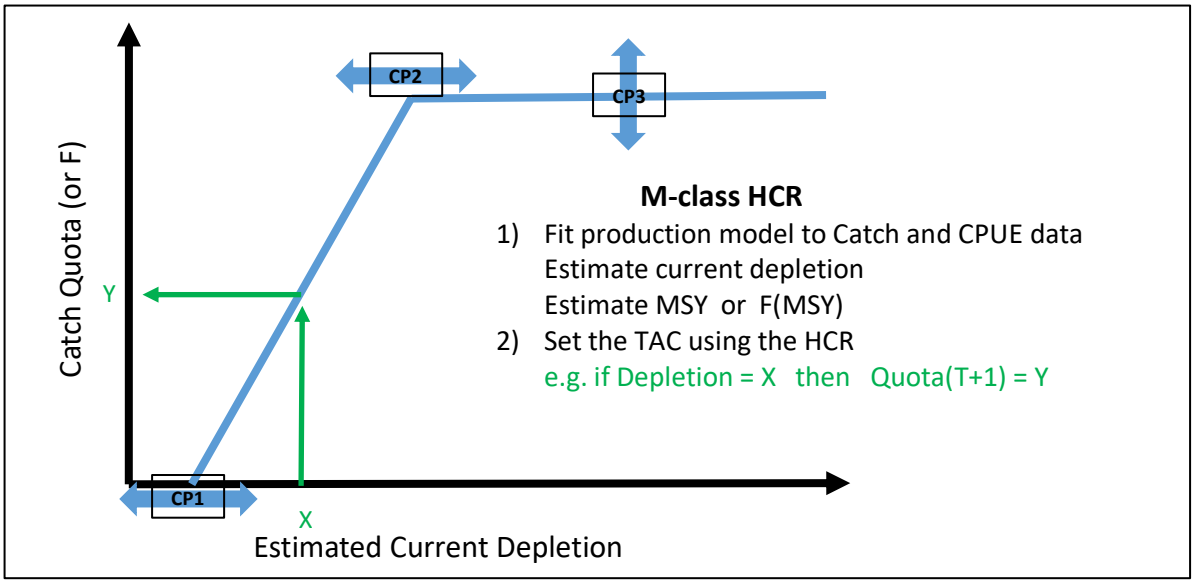

Figure 1. The model-based (M-class) MPs involve two steps: 1) fitting a simple surplus production model, and 2) applying a Harvest Control Rule (HCR) to the model estimates. The individual M-class MPs differ in terms of the Control Parameters (CP1-CP3) that define the shape of the HCR (and potentially the TAC change constraints). In the examples presented here, CP1 and CP2 were constant (at a range of different levels in different candidate MPs), while numerical optimization was used to find the value of CP3 that achieves the precise tuning objective.

"D" class (data-based) MPs

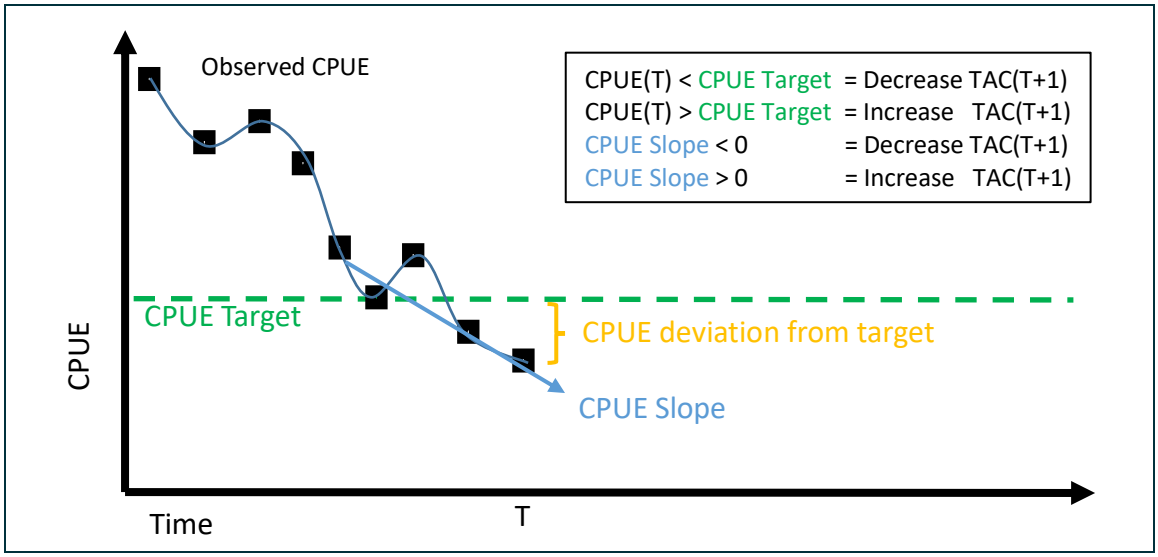

Figure 2. The data-based (D-class) MPs attempt to manage the fishery to achieve a target value of standardized longline CPUE (annual, regionally-averaged). The next TAC is increased relative to the current TAC if current CPUE is above the target CPUE and the CPUE trend is increasing. Conversely, the next TAC is decreased relative to the current TAC if current CPUE is below the target CPUE and the CPUE trend is decreasing. If the CPUE location relative to the target and CPUE slope are in opposite directions, the TAC change could be in either direction, depending on the magnitude of these indicators, and the associated control parameters. Control parameters include: 1) the number of years in the CPUE slope calculation, 2) responsiveness to CPUE target deviation, 3) responsiveness to CPUE slope and 4) the CPUE target (the tuning parameter in this case). The TAC change constraint will also affect MP behaviour.

Summary of Bigeye Candidate MP Performance

MP rankings against key performance indicators are presented in Table 1 and figs. 3-9 illustrate performance characteristics. More detailed performance tables are included in Appendix 1 (summarized over different time windows). We highlight the following key points:

- The tuning levels defined by TCMP-02 appear to span a reasonable range of the performance trade-off space.
- The tuning levels are generally more important than the MP-class in determining performance.
- All of the interim tuning objectives result in 20 year average projected catches that are likely to be somewhat higher than current catches. However, due to the substantial uncertainty in the system, the realized catches could be considerably higher or lower than current.
- The most aggressive MPs (tuned for B1), tend to increase catches initially, to lower the probability of being in the Kobe green zone. This results in substantial biomass risk toward the latter part of the projection period (e.g. after 2030), and the requirement to eventually lower catches. This is evident to a lesser degree for tuning objective B2. MPs tuned for B3 suggest very stable future dynamics.
- Since there has been no direct management action constraining bigeye catches in recent years, it is not clear that the high catches associated with the more aggressive tuning levels (B1 - B2) would be attained under current industry conditions.

Feedback Requests for the TCMP

The following points are provided to suggest the type of feedback that would be most useful for scientists for the next iteration.

1) Is it possible to further reduce the number of tuning objectives to one or two? The single most important factor defining MP behaviour is identifying where on the catch and biomass risk trade-off the Commission would like to be over the medium term.

2) Would tuning objectives be easier to interpret and communicate if they were expressed in different units? e.g. The current tuning levels could be re-expressed in terms of the 20 year averaged Kobe plot (Figure 5), with almost the same outcome:

- B1 ≈ Pr(mean(B(2021:2040)/B(MSY)) > 1.20) = 0.5
- B2 ≈ Pr(mean(B(2021:2040)/B(MSY)) > 1.35) = 0.5
- B3 ≈ Pr(mean(B(2021:2040)/B(MSY)) > 1.45) = 0.5

3) The MP developers tend to assume that stability in catch and biomass risk over time is desirable for bigeye. Are there other time series behaviours that the developers should be aiming to produce?

Table 1. Performance of candidate MPs with respect to key performance measures (averaged over the period 2021-2040). Shading indicates the relative performance (darker = better).

	Performance Measure				
Management Procedure	SB/SB_{MSY}	Prob(Green)	Prob(SB>limit)	Mean Catch	Catch Variability
MB1	1.21 (0.79-1.79)	0.59	0.81	103.9 (80.5-125.9)	5.25
MB2	1.18 (0.81-1.77)	0.58	0.83	106.5 (88.2-125.8)	4.90
MB3	1.38 (0.95-1.88)	0.67	0.88	98.0 (74.4-120.9)	5.08
DB1	1.33 (0.92-1.86)	0.67	0.88	102.1 (81.6-120.1)	4.77
DB2	1.46 (1.06-1.94)	0.73	0.92	94.3 (72.9-115.8)	4.67
DB3	1.46 (1.06-1.97)	0.74	0.93	91.7 (72.0-111.6)	4.79

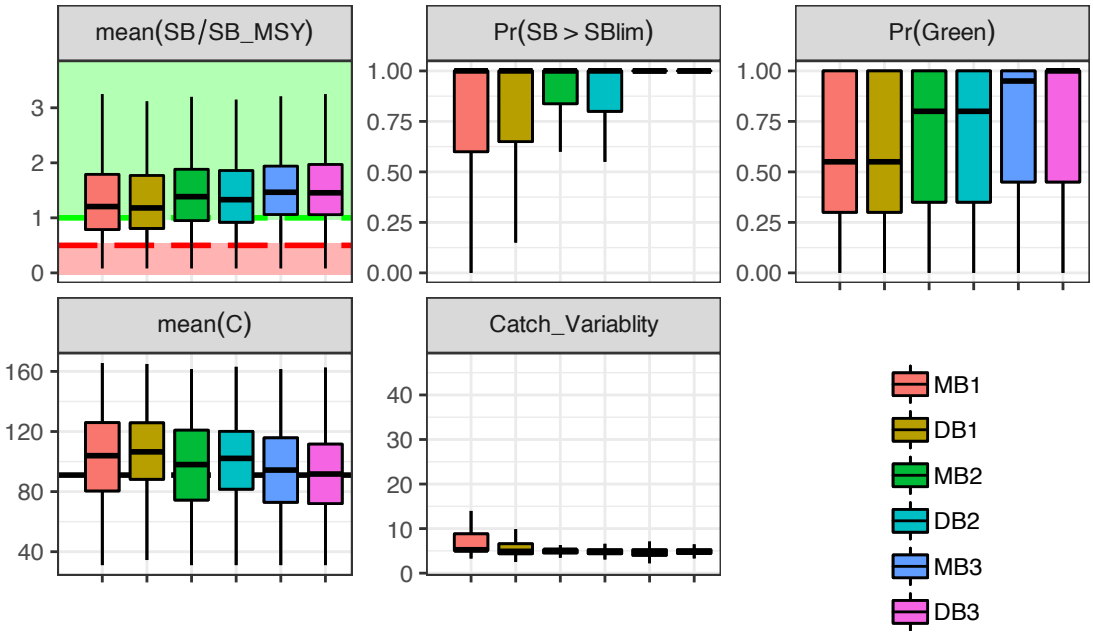

Figure 3. Boxplots comparing candidate MPs with respect to key performance measures averaged over the period 2021 - 2040. Horizontal line is the median, boxes represent 25th - 75th percentiles, thin lines represent 10th - 90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB_{MSY} performance measure. The horizontal dashed black line is 2017 catch.

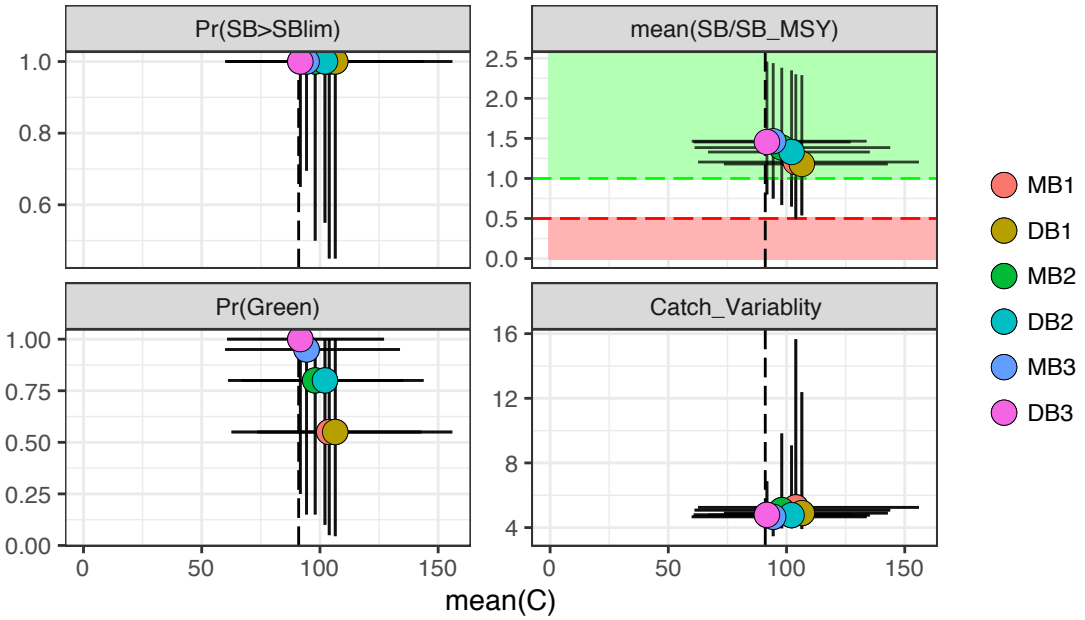

Figure 4. Trade-off plots comparing candidate MPs with respect to catch on the X-axis, and 4 other key performance measures on the Y-axis, each averaged over the period 2021 - 2040. Circle is the median, lines represent 10th-90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB$_{MSY}$ performance measure. The dashed vertical black line is 2017 catch.

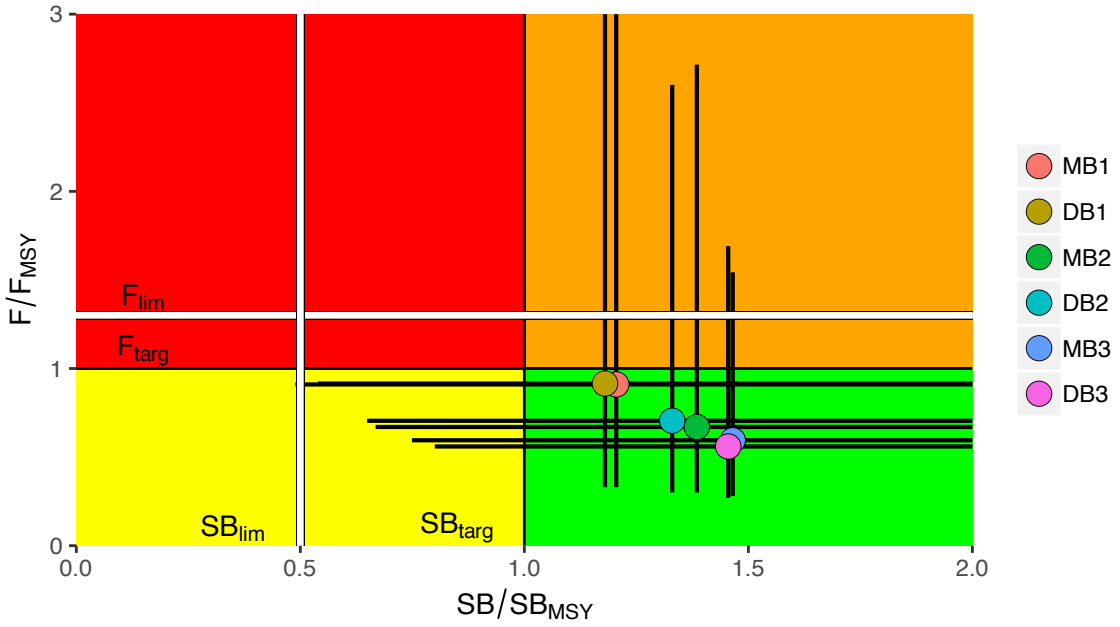

Figure 5. Kobe plot comparing candidate MPs on the basis of the expected 20 year average (2021-2040) performance. Circle is the median, lines represent 10th-90th percentiles.

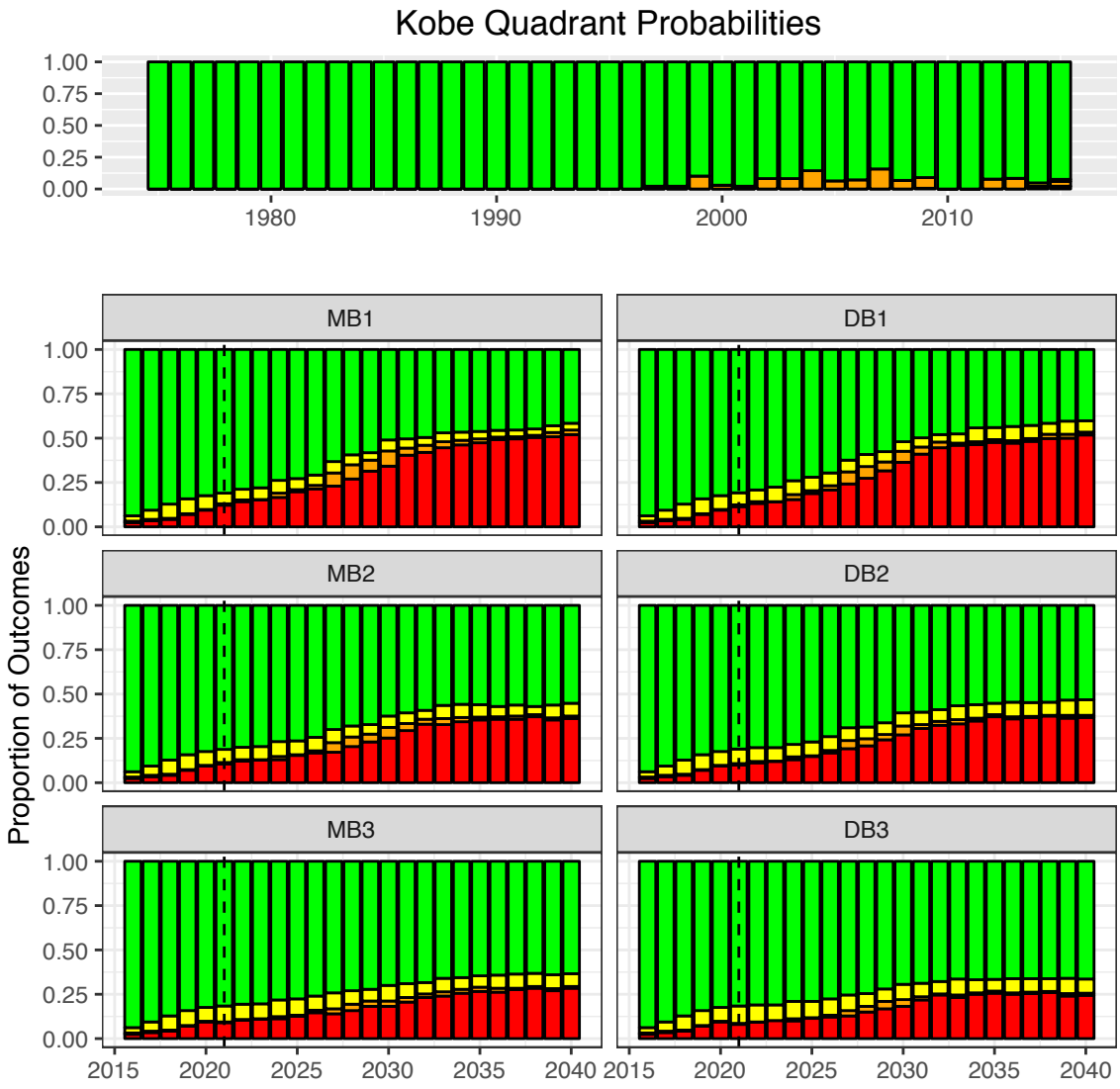

Figure 6. Proportion of simulations in each of the Kobe quadrants over time for each of the candidate MPs. Historical estimates are included in the top panel. The lower panels are projections, with the first MP application indicated by the broken vertical line (2021).

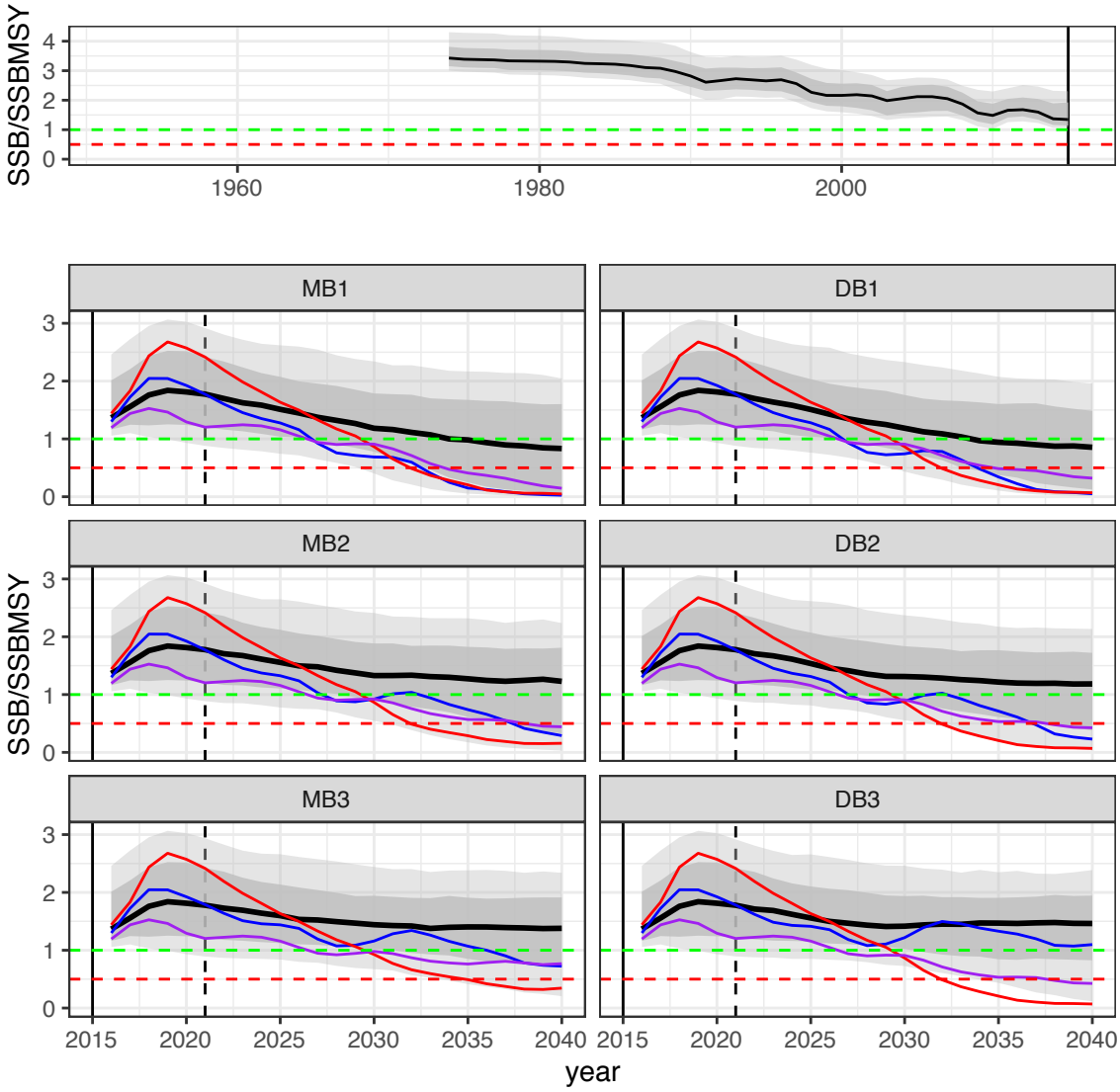

Figure 7. Time series of spawning stock size for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.

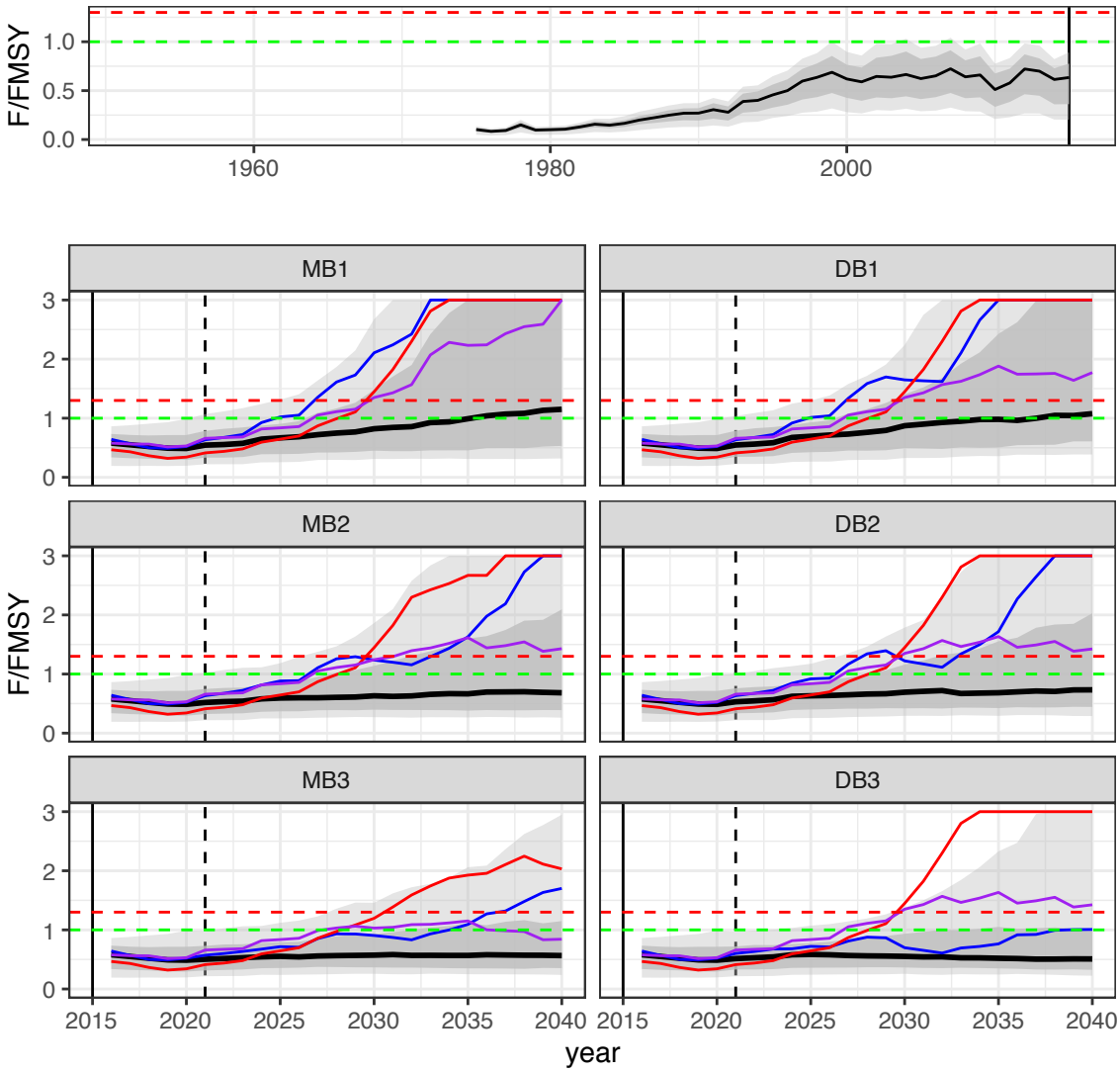

Figure 8. Time series of fishing intensity (Upper bound truncated at F = 3) for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.

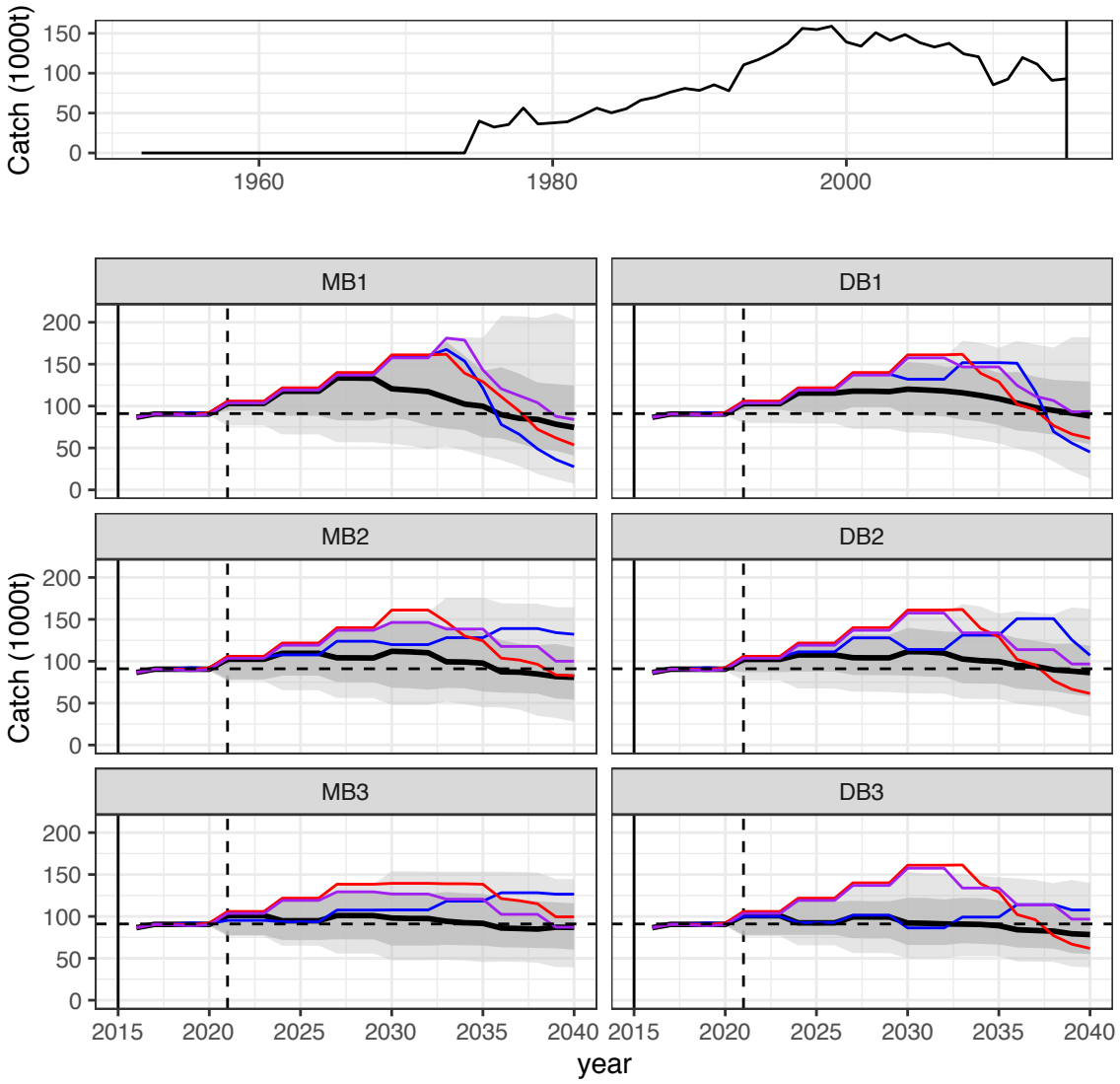

Figure 9. Time series of catch for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. The broken black horizontal line represents recent (2017) catch. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.

Appendix 1. Candidate Management Procedure summary performance tables for a range of time periods (aggregated over regions and fisheries).

Table A1a. Candidate MP performance for standard IOTC performance measures for the year 2021.

Status : maximise stock status		**1 year average**					
		MB1	**MB2**	**MB3**	**DB1**	**DB2**	**DB3**
Mean spawner biomass relative to pristine	SB/SB_0	0.46	0.46	0.46	0.46	0.46	0.46
Minimum spawner biomass relative to pristine	SB/SB_0	0.46	0.46	0.46	0.46	0.46	0.46
Mean spawner biomass relative to SBMSY	SB/SB_{MSY}	1.77	1.77	1.78	1.78	1.78	1.78
Mean fishing mortality relative to FMSY	F/F_{tar}	0.54	0.54	0.52	0.53	0.50	0.51
Mean fishing mortality relative to target	F/F_{MSY}	0.54	0.54	0.52	0.53	0.50	0.51
Probability of being in Kobe green quadrant	SB,F	0.83	0.83	0.83	0.83	0.84	0.83
Probability of being in Kobe red quadrant	SB,F	0.12	0.11	0.11	0.10	0.09	0.08
Safety : maximise the probability of remaining above low stock status (i.e. minimise risk)							
Probability of spawner biomass being above 20% of SB0	SB	0.99	0.99	0.99	0.99	0.99	0.99
Probability of spawner biomass being above BLim	SB	1.00	1.00	1.00	1.00	1.00	1.00
Yield : maximise catches across regions and gears							
Mean catch (1000 t)	C	103.21	102.91	102.36	102.20	101.07	100.79
Mean relative CPUE (aggregate)	C	0.83	0.84	0.79	0.80	0.77	0.78
Mean catch relative to MSY	C/MSY	0.85	0.85	0.85	0.85	0.85	0.85
Stability: maximise stability in catches to reduce commercial uncertainty							
Mean absolute proportional change in catch	C	15.00	15.00	15.00	15.00	15.00	15.00
% Catch coefficient of variation	C	NA	NA	NA	NA	NA	NA
Probability of shutdown	C	0.00	0.00	0.00	0.00	0.00	0.00

Table A1b. Candidate MP performance for standard IOTC performance measures for the 5 year period 2021-2024.

Status : maximise stock status		**5 year average**					
		MB1	**MB2**	**MB3**	**DB1**	**DB2**	**DB3**
Mean spawner biomass relative to pristine	SB/SB_0	0.43	0.43	0.43	0.43	0.44	0.43
Minimum spawner biomass relative to pristine	SB/SB_0	0.38	0.38	0.39	0.38	0.39	0.39
Mean spawner biomass relative to SBMSY	SB/SB_{MSY}	1.65	1.65	1.67	1.66	1.68	1.68
Mean fishing mortality relative to FMSY	F/F_{tar}	0.60	0.61	0.55	0.58	0.54	0.56
Mean fishing mortality relative to target	F/F_{MSY}	0.60	0.61	0.55	0.58	0.54	0.56
Probability of being in Kobe green quadrant	SB,F	0.79	0.79	0.81	0.81	0.82	0.83
Probability of being in Kobe red quadrant	SB,F	0.15	0.14	0.12	0.12	0.10	0.09
Safety : maximise the probability of remaining above low stock status (i.e. minimise risk)							
Probability of spawner biomass being above 20% of SB0	SB	0.96	0.96	0.97	0.97	0.98	0.98
Probability of spawner biomass being above BLim	SB	0.99	0.99	0.99	0.99	0.99	0.99
Yield : maximise catches across regions and gears							
Mean catch (1000 t)	C	108.59	107.43	103.91	103.84	98.32	97.65
Mean relative CPUE (aggregate)	C	0.85	0.86	0.81	0.83	0.77	0.79
Mean catch relative to MSY	C/MSY	0.84	0.83	0.86	0.84	0.87	0.86
Stability: maximise stability in catches to reduce commercial uncertainty							
Mean absolute proportional change in catch	C	6.00	6.00	6.00	6.00	6.00	6.00
% Catch coefficient of variation	C	0.08	0.08	0.08	0.08	0.08	0.08
Probability of shutdown	C	0.00	0.00	0.00	0.00	0.00	0.00

Table A1c. Candidate MP performance for standard IOTC performance measures for the 10 year period 2021-2030.

Status : maximise stock status		**10 year average**					
		MB1	**MB2**	**MB3**	**DB1**	**DB2**	**DB3**
Mean spawner biomass relative to pristine	SB/SB_0	0.39	0.37	0.40	0.39	0.41	0.41
Minimum spawner biomass relative to pristine	SB/SB_0	0.29	0.29	0.32	0.31	0.34	0.33
Mean spawner biomass relative to SBMSY	SB/SB_{MSY}	1.48	1.46	1.55	1.52	1.60	1.57
Mean fishing mortality relative to FMSY	F/F_{tar}	0.70	0.72	0.60	0.66	0.56	0.59
Mean fishing mortality relative to target	F/F_{MSY}	0.70	0.72	0.60	0.66	0.56	0.59
Probability of being in Kobe green quadrant	SB,F	0.71	0.70	0.76	0.75	0.79	0.80
Probability of being in Kobe red quadrant	SB,F	0.20	0.20	0.16	0.16	0.13	0.12
Safety : maximise the probability of remaining above low stock status (i.e. minimise risk)							
Probability of spawner biomass being above 20% of SB0	SB	0.90	0.90	0.93	0.93	0.95	0.95
Probability of spawner biomass being above BLim	SB	0.95	0.96	0.97	0.97	0.98	0.98
Yield : maximise catches across regions and gears							
Mean catch (1000 t)	C	118.83	111.39	104.94	105.82	96.22	96.36
Mean relative CPUE (aggregate)	C	0.89	0.91	0.80	0.85	0.76	0.77
Mean catch relative to MSY	C/MSY	0.82	0.81	0.86	0.83	0.88	0.87
Stability: maximise stability in catches to reduce commercial uncertainty							
Mean absolute proportional change in catch	C	6.00	5.34	6.00	5.31	5.47	5.59
% Catch coefficient of variation	C	0.15	0.12	0.14	0.11	0.13	0.11
Probability of shutdown	C	0.00	0.00	0.00	0.00	0.00	0.00

Table A1d. Candidate MP performance for standard IOTC performance measures for the 20 year period 2021-2040.

Status : maximise stock status		**20 year average**					
		MB1	**MB2**	**MB3**	**DB1**	**DB2**	**DB3**
Mean spawner biomass relative to pristine	SB/SB_0	0.32	0.31	0.37	0.36	0.40	0.40
Minimum spawner biomass relative to pristine	SB/SB_0	0.16	0.18	0.24	0.24	0.27	0.29
Mean spawner biomass relative to SBMSY	SB/SB_{MSY}	1.21	1.18	1.38	1.33	1.46	1.46
Mean fishing mortality relative to FMSY	F/F_{tar}	0.91	0.92	0.67	0.70	0.59	0.56
Mean fishing mortality relative to target	F/F_{MSY}	0.91	0.92	0.67	0.70	0.59	0.56
Probability of being in Kobe green quadrant	SB,F	0.59	0.58	0.67	0.67	0.73	0.74
Probability of being in Kobe red quadrant	SB,F	0.34	0.33	0.25	0.25	0.19	0.18
Safety : maximise the probability of remaining above low stock status (i.e. minimise risk)							
Probability of spawner biomass being above 20% of SB0	SB	0.74	0.75	0.82	0.82	0.87	0.88
Probability of spawner biomass being above BLim	SB	0.81	0.83	0.88	0.88	0.92	0.93
Yield : maximise catches across regions and gears							
Mean catch (1000 t)	C	103.92	106.47	97.98	102.12	94.34	91.70
Mean relative CPUE (aggregate)	C	0.82	0.86	0.77	0.80	0.74	0.72
Mean catch relative to MSY	C/MSY	0.70	0.69	0.80	0.77	0.86	0.83
Stability: maximise stability in catches to reduce commercial uncertainty							
Mean absolute proportional change in catch	C	5.25	4.90	5.08	4.77	4.67	4.79
% Catch coefficient of variation	C	0.24	0.19	0.19	0.17	0.17	0.16
Probability of shutdown	C	0.02	0.01	0.01	0.01	0.01	0.00