IOTC Bigeye Tuna Management Procedure Evaluation Update May 2018[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 case Operating Model (simulator) is being iteratively developed in line with IOTC technical working party requests (WPTT and WPM). Scientific and technical concerns have been identified in these MP evaluations that require further review.
- Several generic MPs have been evaluated for each of the tuning objectives requested by the TCMP-01 (2017). A small subset is presented here to illustrate typical performance.
- This is an iterative process, where a main feedback priority for the TCMP-02 is to refine management objectives and MP tuning targets.
- Phase 2 scientific and technical support funding ends in Dec2018.

Bigeye MP Development Guidance from TCMP-01 (2017)

The tuning objective refers to a key management objective that the MPs can achieve precisely (e.g. achieving SB ≥ SB_{MSY} with a 50% probability by 2024). The tuning objective normally 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. The TCMP 2017 defined 4 interim bigeye tuning objectives for exploration:

TB1: Pr(mean(SB(2019:2038))>=SB(MSY)) = 0.5. Average Spawning biomass (SB) over the period 2019-2038 exceeds SB_{MSY} in exactly 50% of the simulations).

TB2: Pr(Kobe green zone 2019:2038) = 0.5. The stock status is in the Kobe green quadrant over the period 2019-2038 exactly 50% of the time (averaged over all simulations).

TB3: Pr(Kobe green zone 2019:2038) = 0.6. The stock status is in the Kobe green quadrant over the period 2019-2038 exactly 60% of the time (averaged over all simulations).

TB4: Pr(Kobe green zone 2019:2038) = 0.7. The stock status is in the Kobe green quadrant over the period 2019-2038 exactly 70% of the time (averaged over all simulations).

TCMP-01 (2017) 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 three characters of the candidate MP name correspond to the tuning objective and the final letter designates the model class, e.g. **TB1.M: tuning = TB1 (above), model-based MP (below)**. Commonly, the tuning objective is more important than the MP type in determining management performance.

"M" class (model-based) MPs

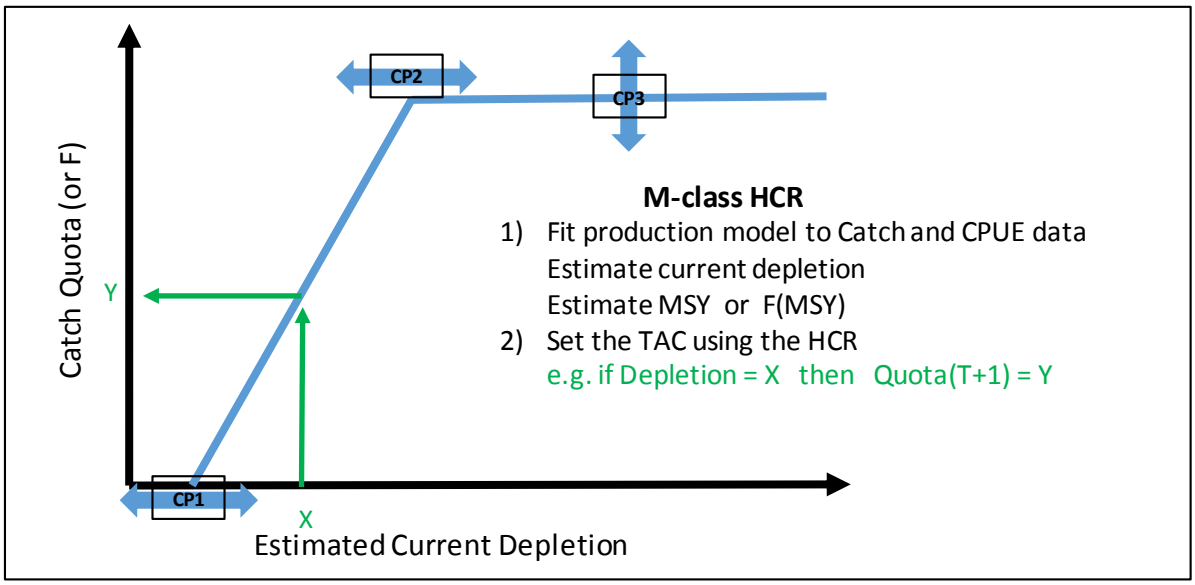

Figure 1. The model-based (M-class) MPs involve two steps: 1) fitting a simple surplus production model, and 2) applying a Harvest Control Rule (HCR) to the model estimates. The individual M-class MPs differ in terms of the Control Parameters (CP1-CP3) that define the shape of the HCR. In the examples 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

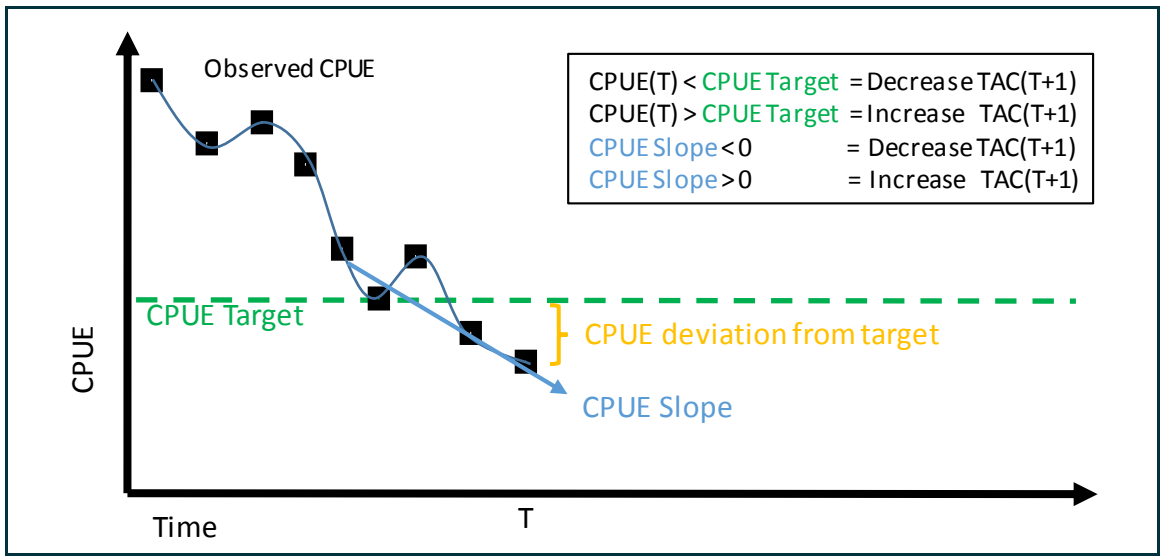

Figure 2. The data-based (D-class) MPs attempt to manage the fishery to achieve a target value of (standardized longline) CPUE. The next TAC is increased relative to the current TAC if current CPUE is above the target CPUE and the CPUE trend is increasing. Conversely, the next TAC is decreased relative 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).

Summary of Bigeye Candidate MP Performance

TCMP-02 represents the first set of results for the bigeye tuna MP evaluations using an operating model that was conditioned in conjunction with the substantial revisions to data inputs and model structure in the 2016 assessment. MP rankings against key performance indicators are presented in Table 1, figs. 3-9 illustrate many performance characteristics and comprehensive tables are presented in Appendix 1. We highlight the following points:

- Given the optimistic stock status for bigeye, we considered additional tuning levels to expand the trade-off space explored, one of which is presented:
    - **TB9** = Pr(mean(SB(2019:2038) >= 1.9 SB(MSY)) = 0.5
- The tuning levels are much more important than the MP-class in determining performance
- In order of decreasing biomass risk, (e.g. probability of exceeding SBlim), the tuning levels are arranged TB1, TB2, TB3, TB4, TB9. The most aggressive tuning level (TB1) could not be achieved with the 15% change constraint (it was raised to 25%).
- The interim tuning objectives TB1 to TB4 all result in average projected catches that are substantially higher than current catches, while TB9 catches are very close to recent catches.
- All tuning levels except TB9 must increase catches to bring down the biomass to the levels required to meet the tuning objectives. This often results in high biomass risk toward the latter part of the projection period (e.g. after 2030). In the most aggressive tuning levels, this would be expected to result in stock collapse.
- Since there has been no direct management action constraining bigeye catches in recent years, it seems unlikely that the high catches associated with the more aggressive tuning levels (TB1 - TB3) would be desirable in the short-term, or achieved as simulated in the MSE. i.e. Currently, there does not appear to be an economic incentive to raise bigeye catches above 87000 t, or they would already be higher (reported catches exceeded 120 000 t from 1995-2005).
- Tuning level TB9 suggests that stable status quo catches can be sustained with relatively low biomass risk. Adopting TB9 would imply a relatively low level of risk tolerance, which could constrain catches to bigeye if economic incentives change in the future.

Feedback Requests for the TCMP

The MP development process will work most effectively if the TCMP can provide further feedback about the management objectives that the scientists should be trying to achieve. The following points are provided to suggest the type of feedback that would be most useful for scientists for future iterations.

The single most important factor is defining where on the catch and biomass risk trade-off relationship the Commission would like to be. This should be defined as a tuning objective, that the scientists can achieve exactly, while providing future MP variations that differ in other respects.

It is useful to define tuning objectives in common units, because the different performance measures tend to be highly correlated and different indicators are likely to be pointing to the same general space. The median SB/SB_{MSY} (as used in TB1 and TB9) is particularly attractive for communication purposes because:

- This value is expressed in the same units as the interim biomass target and limit reference points.

- SB/SB_{MSY} has a direct mapping in the standard figures (3,4 and 5). i.e. The median SB/SB_{MSY} for the TB1-tuned MPs fall precisely on $SB_{target} = SB_{MSY}$. The probability of being in the green Kobe quadrant does not map directly onto the standard plots.
- Within the current Operating Model, TB2 - TB4 can be approximately translated into these units, i.e. from Table 1:
    - TB1 = Pr(mean(SB(2019:2038)>=1.00 SB(MSY)) = 0.5 (unchanged)
        - Average SB over the period 2019-2038 exceeds SB_{MSY} in exactly 50% of the simulations.
    - TB2 ≈ Pr(mean(SB(2019:2038)>=1.23 SB(MSY)) = 0.5.
        - The stock status is in the Kobe green quadrant over the period 2019-2038 exactly 50% of the time (averaged over all simulations) is very similar to: average SB over the period 2019-2038 exceeds 1.23 SB_{MSY} in exactly 50% of the simulations.
    - TB3 ≈ Pr(mean(SB(2019:2038)>=1.40 SB(MSY)) = 0.5.
        - The stock status is in the Kobe green quadrant over the period 2019-2038 exactly 50% of the time (averaged over all simulations) is very similar to: average SB over the period 2019-2038 exceeds 1.40 SB_{MSY} in exactly 50% of the simulations.
    - TB4 ≈ Pr(mean(SB(2019:2038)>=1.56 SB(MSY)) = 0.5.
        - The stock status is in the Kobe green quadrant over the period 2019-2038 exactly 50% of the time (averaged over all simulations) is very similar to: average SB over the period 2019-2038 exceeds 1.56 SB_{MSY} in exactly 50% of the simulations.
    - TB9 = Pr(mean(SB(2019:2038)>=1.90 SB(MSY)) = 0.5 (unchanged)
        - Average SB over the period 2019-2038 exceeds 1.90 SB_{MSY} in exactly 50% of the simulations.
- Tuning based on median (50th) percentiles are likely to be more robust to Operating Model review and revision than objectives based on "high probabilities", because uncertainty quantification is a difficult process, and the statistical inferences are likely to be more robust near the middle of the simulation distributions.

If a single tuning objective can be agreed, this would allow focussed development of MPs that are directly comparable, and which differ with respect to secondary management performance measures. To make detailed consideration of MP trade-offs, it has proved useful in other fora to focus on a maximum of about 6 MPs. If a range of tuning objectives is still desired at this time, we would suggest aiming for a maximum of 3. These can be further refined in subsequent iterations and interpolation between performance of close tuning objectives is reasonable for discussion purposes. Targeted MP development might be used to address concerns about the time series of MP performance in a manner that is more nuanced than the generic HCRs applied here.

The TCMP may want to reconsider the tuning timeframe. The interim tuning objectives (and most of the summary plots) are based on averages over the years 2019-2038. It would be unusual to expect an MP to operate for 20 years without review and revision, so it may be reasonable to focus performance measures on a shorter (e.g. 10-15 year timeframe).

Table 1. Performance of candidate MPs with respect to key performance measures (averaged over the period 2019 -2038). Shading indicates the relative performance (darker = better).

	Performance Measure				
Management Procedure	SB/SB_{MSY}	Prob(Green)	Prob(SB>limit)	Mean Catch	Catch Variability
TB1.M	1 (0.65-1.4)	0.37	0.65	119 (96-157)	15
TB1.D	1 (0.7-1.4)	0.37	0.67	130 (107-167)	13
TB2.M	1.2 (0.83-1.8)	0.5	0.8	136 (116-149)	5.3
TB2.D	1.2 (0.83-1.8)	0.5	0.78	134 (110-152)	5.6
TB3.M	1.4 (1-1.9)	0.6	0.88	128 (113-141)	4.7
TB3.D	1.4 (1-1.8)	0.59	0.86	121 (97-145)	5.2
TB4.M	1.5 (1.2-1.9)	0.7	0.94	118 (102-133)	4.5
TB4.D	1.6 (1.2-2)	0.7	0.92	113 (91-131)	4.7
TB9.M	1.9 (1.5-2.3)	0.9	0.99	92 (76-108)	4.4
TB9.D	1.9 (1.5-2.3)	0.91	0.99	89 (80-100)	3.8

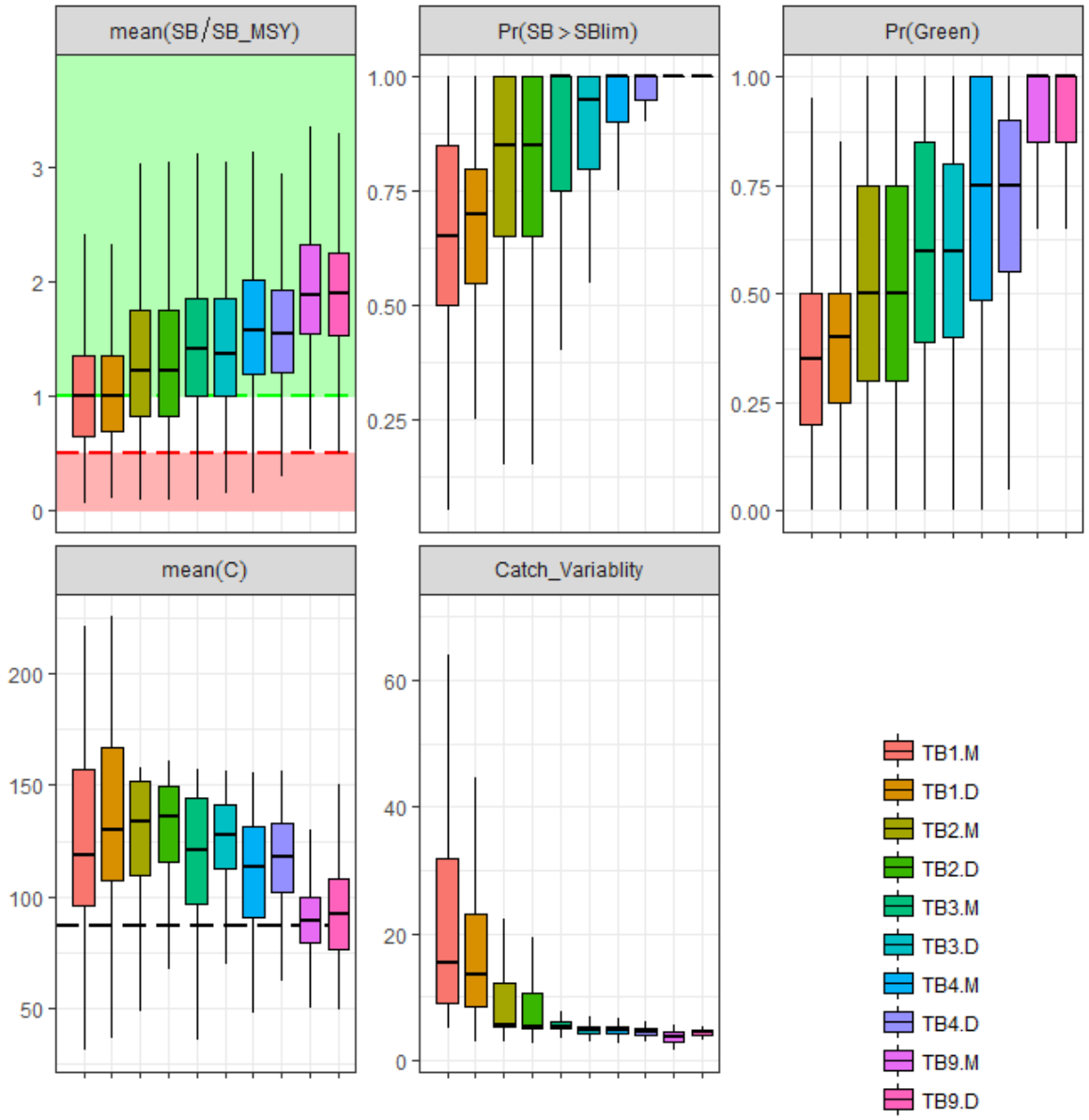

Figure 3. Boxplots comparing candidate MPs with respect to key performance measures averaged over the period 2019 - 2038. Horizontal line is the median, boxes represent 25th - 75th percentiles, thin lines represent 10th - 90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB_{MSY} performance measure. The horizontal dashed black line is 2016 catch.

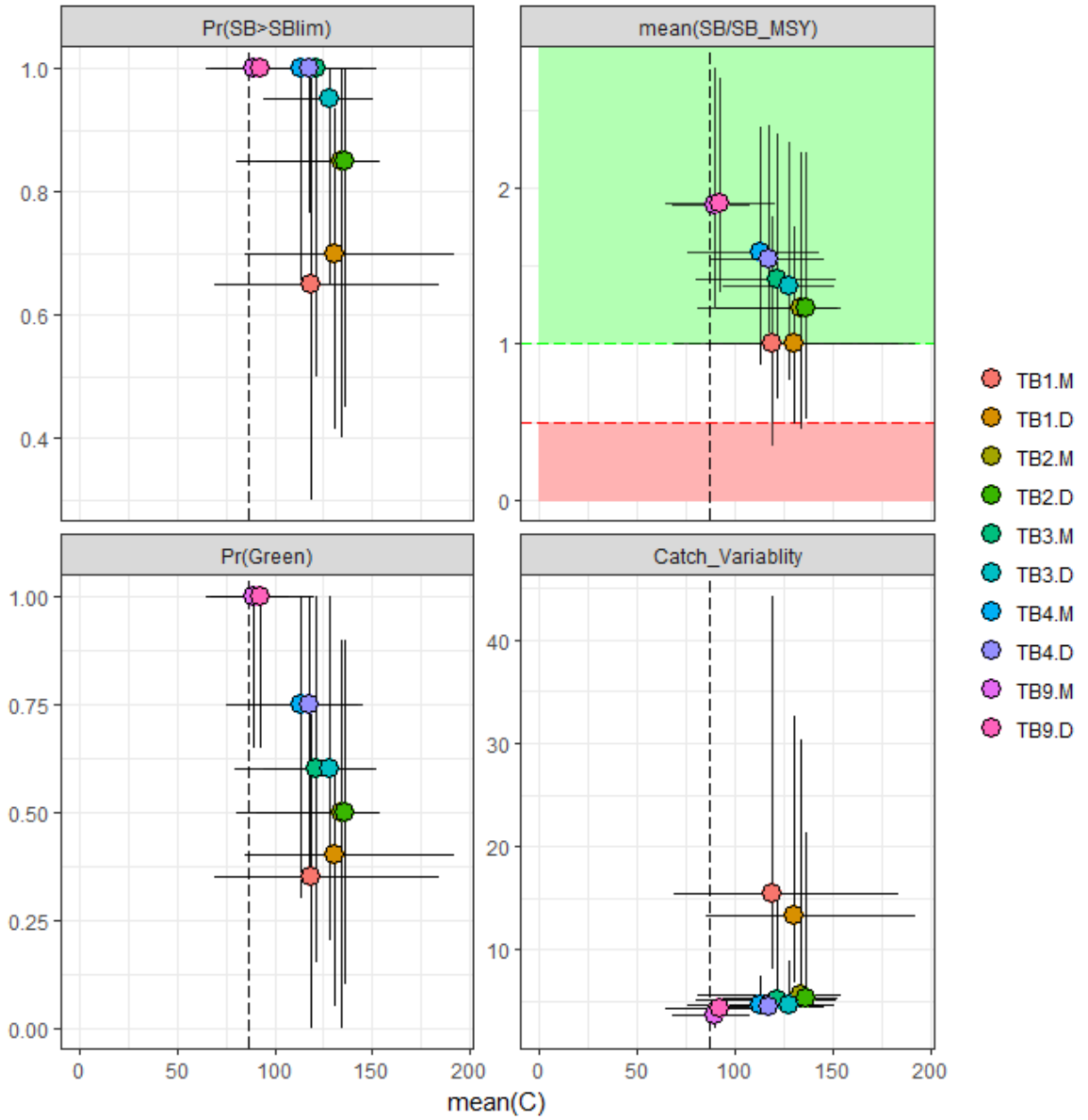

Figure 4. Trade-off plots comparing candidate MPs with respect to catch on the X-axis, and 4 other key performance measures on the Y-axis, each averaged over the period 2019 - 2038. Circle is the median, lines represent 10th-90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB_{MSY} performance measure. The dashed vertical black line is 2016 catch.

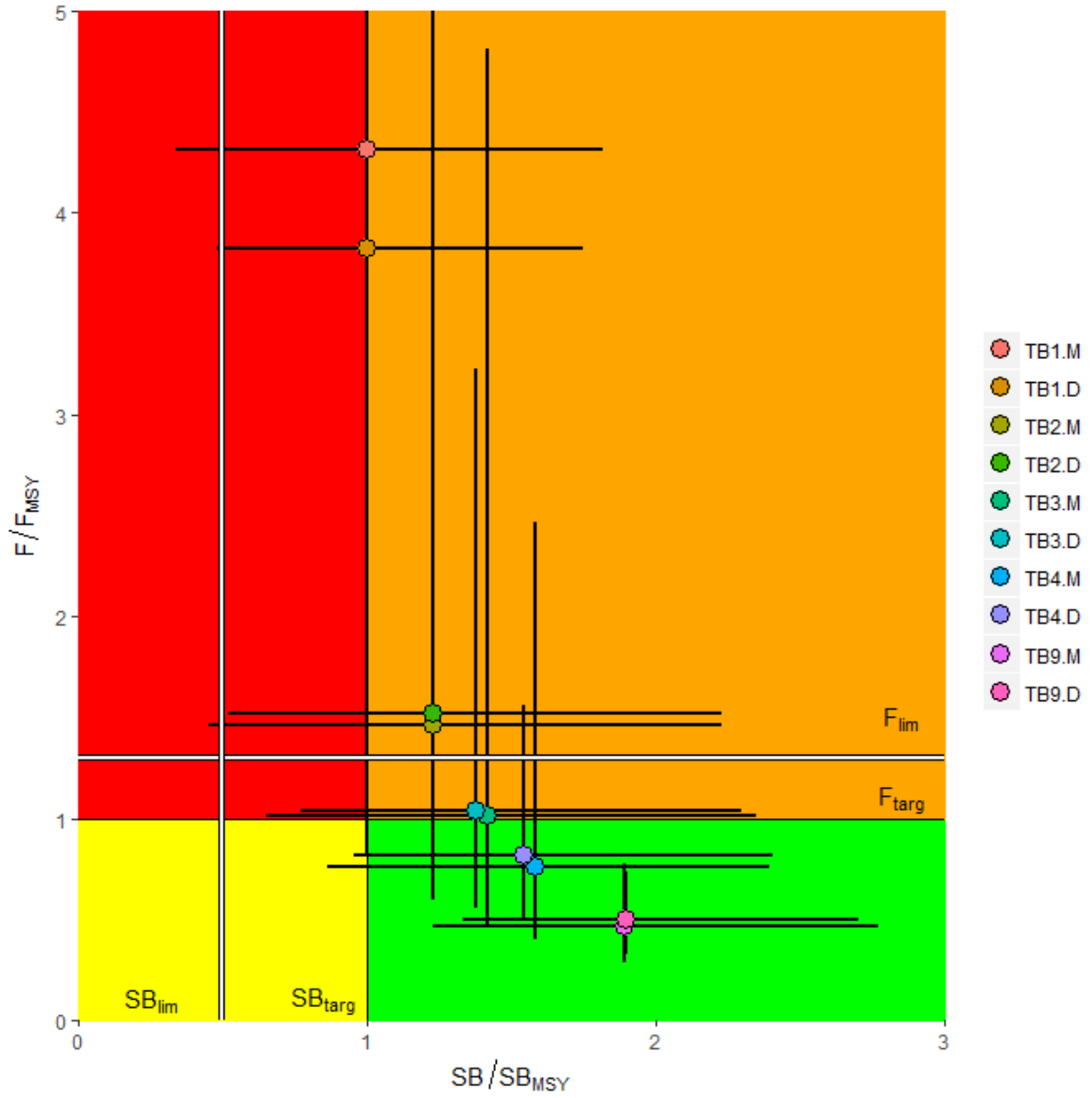

Figure 5. Kobe plot comparing candidate MPs on the basis of the expected 20 year average (2019-2038) performance. Circle is the median, lines represent 10th-90th percentiles.

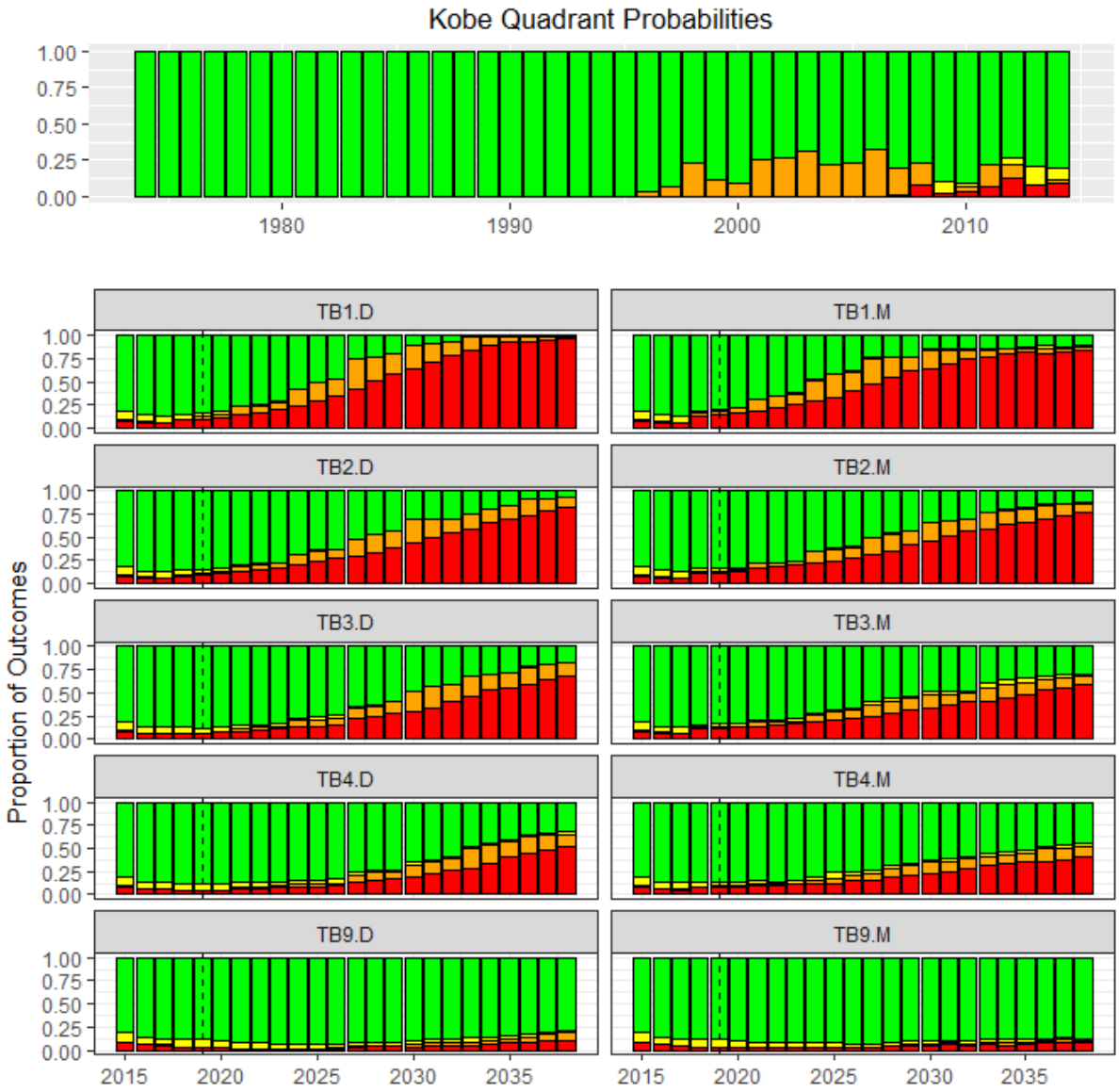

Figure 6. Proportion of simulations in each of the Kobe quadrants over time for each of the candidate MPs. Historical estimates are included in the top panel. The lower panels are projections, with the first MP application indicated by the broken vertical line (2019).

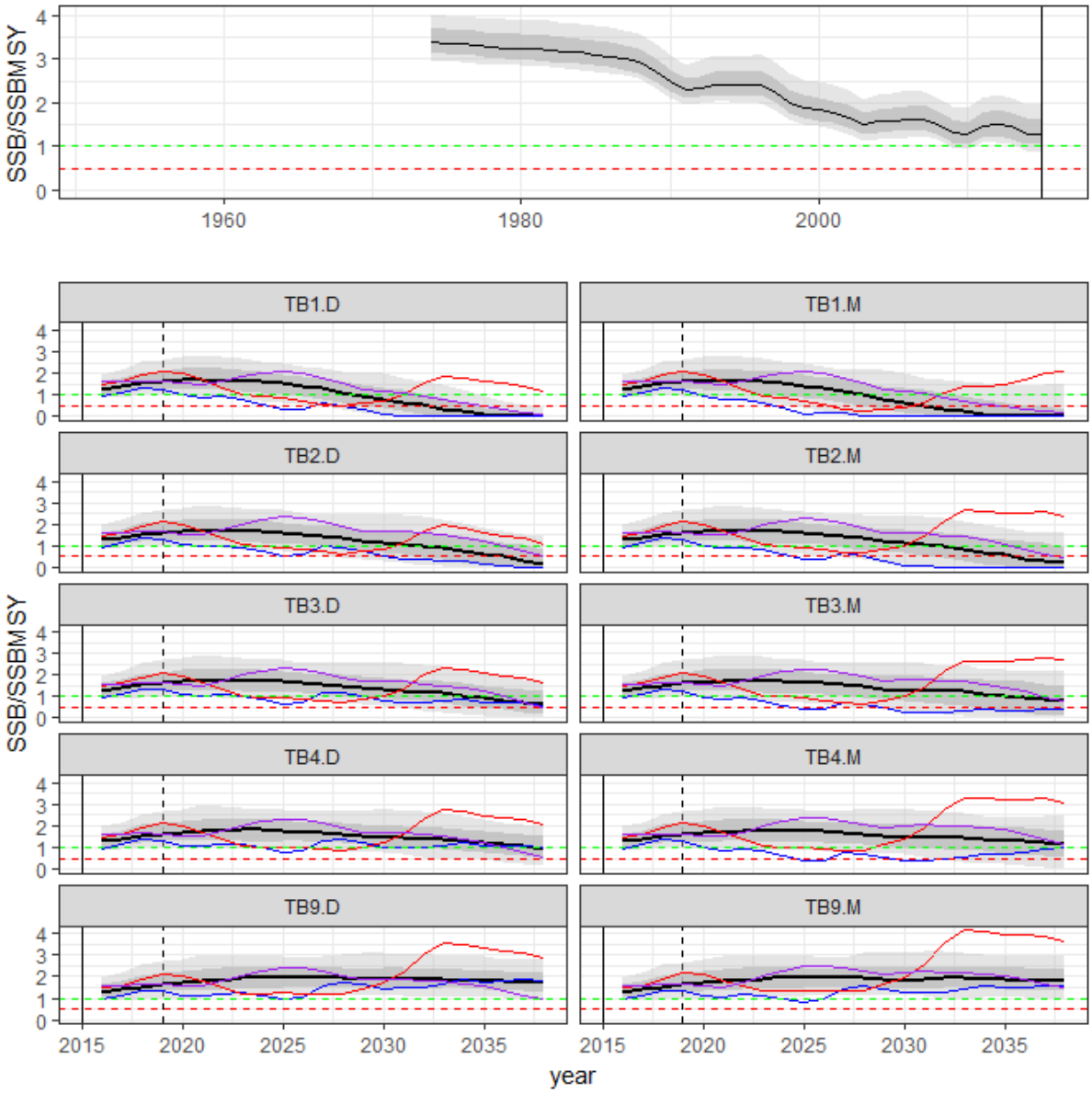

Figure 7. Time series of spawning stock size for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken 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.

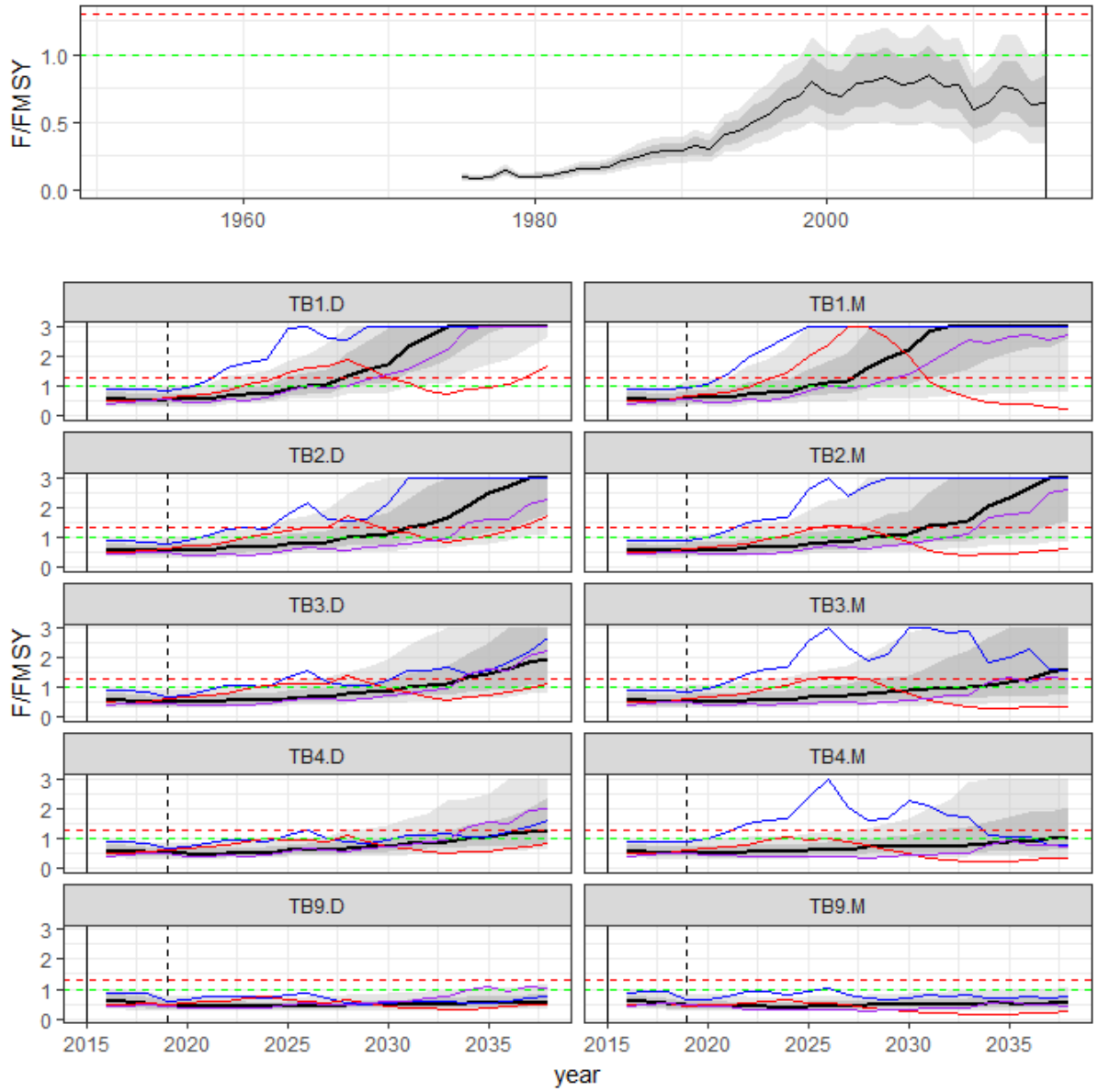

Figure 8. Time series of fishing intensity (Upper bound truncated at F = 3) for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical 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.

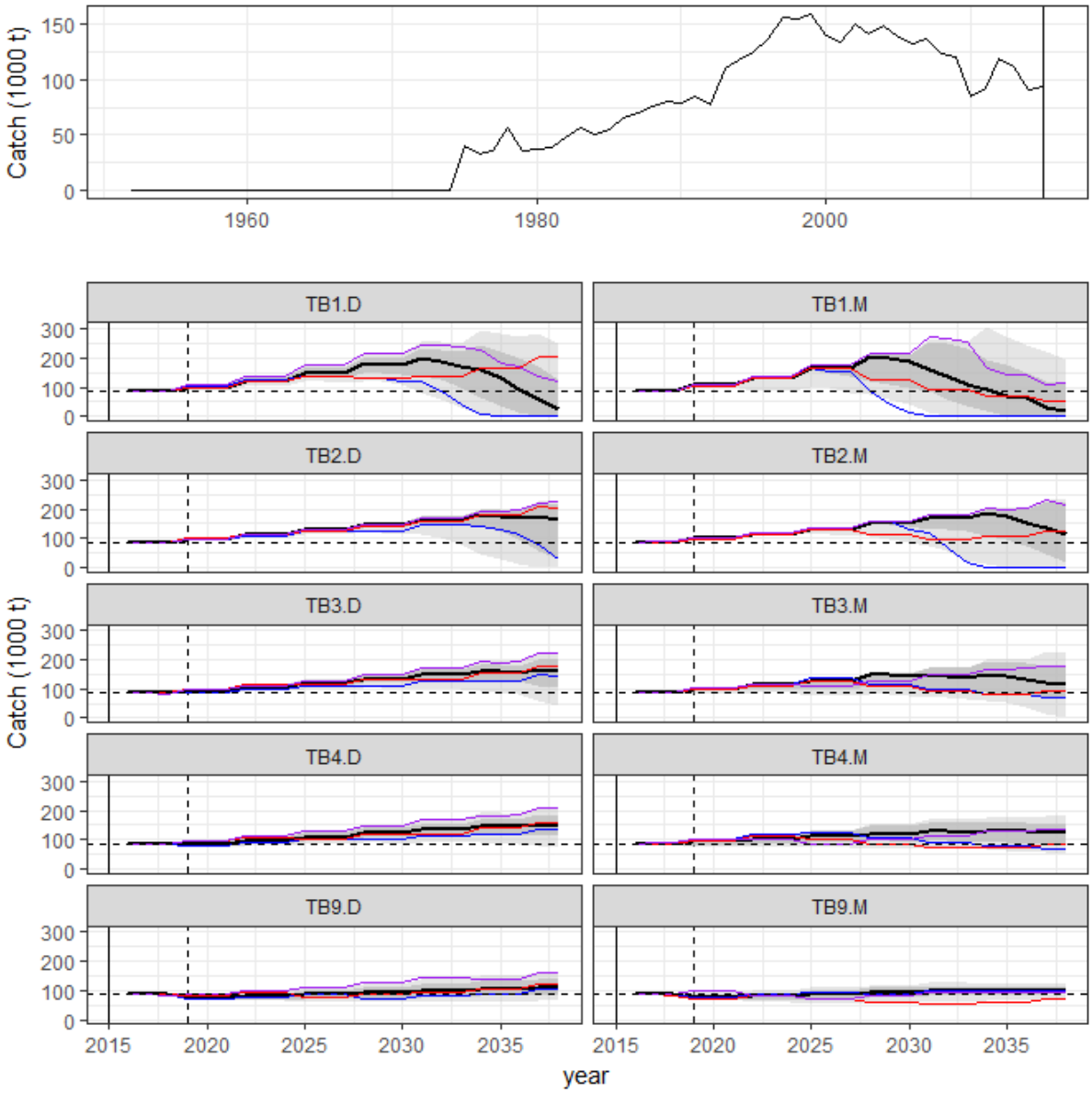

Figure 9. Time series of catch for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line 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 (2016) 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 (A1 = aggregate statistics; A2 = Catch by fishery and standardized CPUE by region).

Table A1a. Candidate MP performance for standard IOTC performance measures for the year 2019.

Status : maximise stock status		**1 year**							
		TB1.M	**TB1.D**	**TB2.M**	**TB2.D**	**TB3.M**	**TB3.D**	**TB4.M**	**TB4.D**
Mean spawner biomass relative to pristine	SB/SB_0	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.46
Minimum spawner biomass relative to pristine	SB/SB_0	0.45	0.452	0.45	0.452	0.45	0.455	0.453	0.457
Mean spawner biomass relative to SBMSY	SB/SB_{MSY}	1.6	1.625	1.62	1.625	1.62	1.64	1.625	1.64
Mean fishing mortality relative to FMSY	F/F_{tar}	0.61	0.57	0.59	0.56	0.56	0.53	0.535	0.495
Mean fishing mortality relative to target	F/F_{MSY}	0.69	0.619	0.64	0.611	0.62	0.569	0.577	0.535
Probability of being in Kobe green quadrant	SB,F	0.85	0.872	0.86	0.872	0.87	0.882	0.878	0.891
Probability of being in Kobe red quadrant	SB,F	0.12	0.082	0.12	0.082	0.11	0.046	0.076	0.033
Safety : maximise the probability of remaining above low stock status (i.e. minimise risk)									
Probability of spawner biomass being above 20% of SB0	SB	0.98	0.993	0.99	0.993	0.99	0.993	0.993	0.993
Probability of spawner biomass being above BLim	SB	1	1	1	1	1	1	1	1
Yield : maximise catches across regions and gears									
Mean catch (1000 t)	C	106.5	98.59	99.5	96.33	96.77	91.18	91.42	86.63
Mean relative CPUE (aggregate)	C	1.05	1.077	1.05	1.078	1.06	1.083	1.06	1.087
Mean catch relative to MSY	C/MSY	0.93	0.856	0.87	0.84	0.85	0.792	0.796	0.75
Stability: maximise stability in catches to reduce commercial uncertainty									
Mean absolute proportional change in catch	C	24.53	14.32	14.96	11.55	14.58	8.767	12.36	9.148
% Catch coefficient of variation	C	0	0	0	0	0	0	0	0
Probability of shutdown	C	0	0	0	0	0	0	0	0

Table A1b. Candidate MP performance for standard IOTC performance measures for the 5 year period 2019-2023.

Status : maximise stock status		**5 year**							
		TB1.M	**TB1.D**	**TB2.M**	**TB2.D**	**TB3.M**	**TB3.D**	**TB4.M**	**TB4.D**
Mean spawner biomass relative to pristine	SB/SB_0	0.46	0.46	0.46	0.47	0.47	0.475	0.48	0.49
Minimum spawner biomass relative to pristine	SB/SB_0	0.39	0.39	0.4	0.4	0.4	0.406	0.405	0.413
Mean spawner biomass relative to SBMSY	SB/SB_{MSY}	1.64	1.65	1.66	1.69	1.7	1.71	1.715	1.73
Mean fishing mortality relative to FMSY	F/F_{tar}	0.67	0.62	0.6	0.59	0.57	0.54	0.535	0.5
Mean fishing mortality relative to target	F/F_{MSY}	0.82	0.7	0.71	0.67	0.67	0.601	0.594	0.551
Probability of being in Kobe green quadrant	SB,F	0.75	0.82	0.82	0.83	0.83	0.868	0.864	0.885
Probability of being in Kobe red quadrant	SB,F	0.16	0.12	0.14	0.11	0.13	0.072	0.086	0.048
Safety : maximise the probability of remaining above low stock status (i.e. minimise risk)									
Probability of spawner biomass being above 20% of SB0	SB	0.94	0.97	0.95	0.97	0.96	0.981	0.975	0.982
Probability of spawner biomass being above BLim	SB	0.97	0.99	0.99	0.99	0.99	0.994	0.995	0.997
Yield : maximise catches across regions and gears									
Mean catch (1000 t)	C	115.18	107.83	104.9	102.01	100.5	96.21	94.15	90.922
Mean relative CPUE (aggregate)	C	1.04	1.08	1.07	1.09	1.08	1.114	1.102	1.132
Mean catch relative to MSY	C/MSY	1	0.94	0.92	0.89	0.88	0.835	0.818	0.786
Stability: maximise stability in catches to reduce commercial uncertainty									
Mean absolute proportional change in catch	C	9.8	7.53	5.81	5.25	5.73	4.534	5.163	4.505
% Catch coefficient of variation	C	12.31	11.642	7.278	7.6	7.43	7.199	7.1623	6.9626
Probability of shutdown	C	0	0	0	0	0	0	0	0

Table A1c. Candidate MP performance for standard IOTC performance measures for the 10 year period 2019 -2029.

Status : maximise stock status		**10 year**							
		TB1.M	**TB1.D**	**TB2.M**	**TB2.D**	**TB3.M**	**TB3.D**	**TB4.M**	**TB4.D**
Mean spawner biomass relative to pristine	SB/SB_0	0.41	0.43	0.45	0.45	0.47	0.47	0.48	0.49
Minimum spawner biomass relative to pristine	SB/SB_0	0.25	0.27	0.32	0.33	0.33	0.34	0.35	0.36
Mean spawner biomass relative to SBMSY	SB/SB_{MSY}	1.5	1.53	1.61	1.63	1.7	1.68	1.77	1.75
Mean fishing mortality relative to FMSY	F/F_{tar}	0.94	0.84	0.74	0.69	0.66	0.63	0.58	0.57
Mean fishing mortality relative to target	F/F_{MSY}	1.47	1.04	0.99	0.87	0.81	0.72	0.66	0.62
Probability of being in Kobe green quadrant	SB,F	0.59	0.69	0.72	0.74	0.76	0.81	0.82	0.86
Probability of being in Kobe red quadrant	SB,F	0.26	0.21	0.2	0.18	0.16	0.11	0.11	0.07
Safety : maximise the probability of remaining above low stock status (i.e. minimise risk)									
Probability of spawner biomass being above 20% of SB0	SB	0.84	0.9	0.9	0.93	0.92	0.96	0.95	0.97
Probability of spawner biomass being above BLim	SB	0.9	0.95	0.95	0.97	0.97	0.98	0.99	0.99
Yield : maximise catches across regions and gears									
Mean catch (1000 t)	C	131.8	127.41	115.99	113.8	108.58	106.55	100.78	99.81
Mean relative CPUE (aggregate)	C	0.93	1.01	1.02	1.06	1.05	1.11	1.11	1.15
Mean catch relative to MSY	C/MSY	1.14	1.1	1.01	0.99	0.94	0.92	0.87	0.86
Stability: maximise stability in catches to reduce commercial uncertainty									
Mean absolute proportional change in catch	C	10.39	8.11	6.02	5.49	5.82	4.93	5.39	4.81
% Catch coefficient of variation	C	22.289	20.716	14.042	13.968	13.121	13.061	12.328	12.355
Probability of shutdown	C	0	0	0	0	0	0	0	0

Table A1d. Candidate MP performance for standard IOTC performance measures for the 20 year period 2019-2038.

Status : maximise stock status		**20 year**							
		TB1.M	**TB1.D**	**TB2.M**	**TB2.D**	**TB3.M**	**TB3.D**	**TB4.M**	**TB4.D**
Mean spawner biomass relative to pristine	SB/SB_0	0.27	0.27	0.34	0.34	0.38	0.39	0.43	0.43
Minimum spawner biomass relative to pristine	SB/SB_0	0	0	0.05	0.04	0.15	0.14	0.22	0.21
Mean spawner biomass relative to SBMSY	SB/SB_{MSY}	1	1	1.23	1.23	1.42	1.37	1.58	1.54
Mean fishing mortality relative to FMSY	F/F_{tar}	4.31	4.19	1.46	1.52	1.01	1.03	0.76	0.82
Mean fishing mortality relative to target	F/F_{MSY}	5.49	4.86	3.31	2.85	2.06	1.67	1.27	1.12
Probability of being in Kobe green quadrant	SB,F	0.37	0.37	0.49	0.5	0.59	0.59	0.69	0.69
Probability of being in Kobe red quadrant	SB,F	0.5	0.51	0.38	0.37	0.29	0.28	0.2	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	0.58	0.59	0.71	0.73	0.79	0.82	0.87	0.88
Probability of spawner biomass being above BLim	SB	0.65	0.67	0.78	0.79	0.85	0.88	0.92	0.93
Yield : maximise catches across regions and gears									
Mean catch (1000 t)	C	124.76	134.58	125.94	128.49	118.29	124.33	110.79	117.03
Mean relative CPUE (aggregate)	C	0.65	0.69	0.8	0.83	0.91	0.95	1.02	1.05
Mean catch relative to MSY	C/MSY	1.04	1.13	1.07	1.09	1.01	1.06	0.94	0.99
Stability: maximise stability in catches to reduce commercial uncertainty									
Mean absolute proportional change in catch	C	21.84	17.54	11.81	9.7	8.17	6.23	5.72	5.08
% Catch coefficient of variation	C	52.741	45.842	34.254	31.538	26.624	24.765	21.268	22.01
Probability of shutdown	C	0.12	0.08	0.05	0.03	0.02	0.01	0	0