IOTC Swordfish Management Strategy Evaluation Update[1]

5th Session IOTC TCMP – 13 & 14 May 2022

Status of the MSE work

- The reference operating model for the Indian Ocean swordfish stock was developed over the last two years and has been endorsed by the IOTC scientific committee. The OM was developed based on the 2019 WPB SS3 assessment, and covered the dynamics of the swordfish until the year 2018. This OM was updated to the current year, by projecting the stock forward based on the reported catches for 2019 and 2020. The choices made in 2019 for the construction of the OM by the previous researcher have not been revisited.
- Further developments to the swordfish MSE included the development and application of two types of candidate MPs, one model based and one data based, and the tuning of these MPs (i.e. defining the MP parameters that achieve a certain management goal) for a range of management objectives over the next 11 to 15 years.
- Technical difficulties were encountered when running the model based MPs, and the results presented below were obtained from simulation in which a perfect stock assessment is assumed, instead of the outcome of the stock assessment proposed for this stock.
- The main feedback priority for the TCMP-05 is to get agreement on the range of proposed MPs to be fully tested, as well as on the current management objectives to be achieved for the tuning procedure.

Swordfish MP Development Guidance from TCMP-04 (2021)

The TCMP NOTED the continued application of the current values for the tuning objectives (50%, 60%, 70%) and constraints on the Management Procedure for swordfish (i.e. TAC set every 3 years, maximum of 15% TAC change constraint, and 3-year lag between data and TAC implementation), NOTING that these will be reviewed by the TCMP in 2022.

Candidate Management Procedures

The swordfish MSE analyses presented here have evaluated two types of MPs:

- A model-based one, in which a surplus-production stock assessment model provides an estimate of current stock status, in terms of current biomass depletion over, which is then used in a harvest control rule to determine advised catch
- A data-based one in which the advised catch is based on the value and recent trend in a CPUE index.

The two types of MPs are presented below and they were furthermore implemented :

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- With a 3 year advice cycle (TAC set for a period of 3 years)
- with a inter-annual TAC variation limit of 15 %, whereby when the implementation of the MP leads to a change in TAC larger (in absolute values) that 15%, the TAC applied is that corresponding to the max 15% change (increase or decrease).
- Assuming that in a given year, y, when advice has to be given for the 3 following years, y+1 to y+3, data are available until the previous year, y-1 (i.e. 1 year data lag)

Model-based MP

- Definition

The model-based MPs (figure 1) involve two steps: 1) fitting a surplus production model to estimate current depletion rate, and 2) applying a Harvest Control Rule (HCR) to the model estimates of current depletion. The shape of the HCR (hockey-stick) is defined by three control parameters :

CP1: minimum stock level below which no fishing (or the least possible) should take place,

CP2: trigger stock level below which Catch advice should be decreased proportionally to current depletion

CP3: maximum catch that can be taken when the stock is estimated to be above the trigger level.

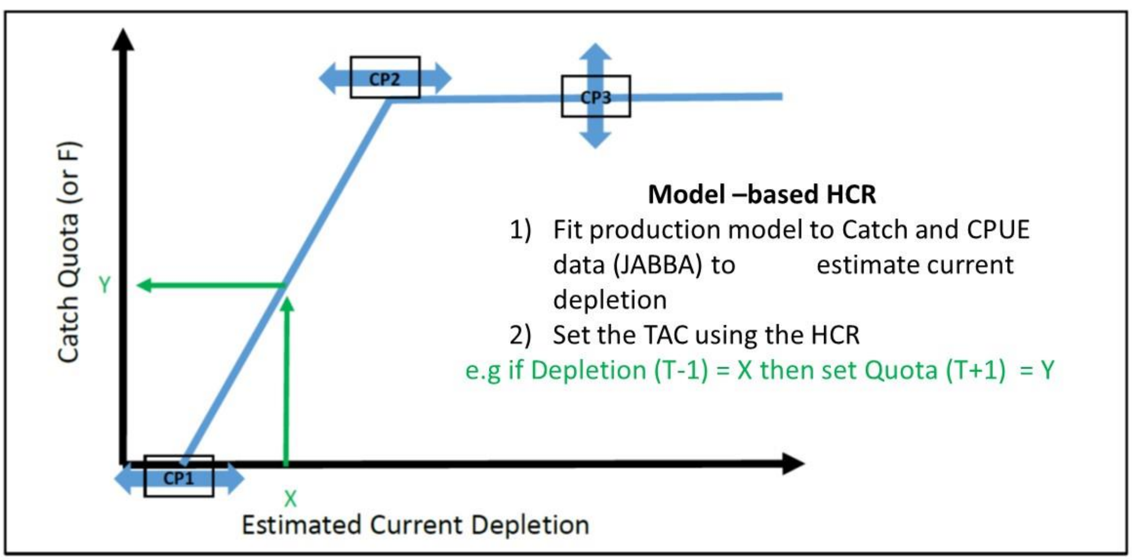

Figure 1. Harvest control rules used in the model-based MP.

- Implementation in the swordfish case

For the swordfish MSE, the current depletion rate is estimated by the surplus production model JABBA, as SB/SB0 (SB0 =virgin biomass). The limit and trigger depletion rates were set at CP1 = 0.1

(a proxy for SB=Blim) and CP2 = 0.4 (a proxy for $SB=SB_{MSY}$) The maximum catch, CP3, was obtained by tuning the MP to achieve the particular management objectives. In agreement with the decision made by the TCMP-03 (2018), the MP was tuned for three tuning objectives corresponding to a probability of being is in the green quadrant of the Kobe plot over the period 2034:2039 of exactly 50%, 60% and 70% (on average over all stock replicates) respectively.

- Technical issues encountered and adaptation

The incorporation of the JABBA stock assessment into the methodological framework used for the swordfish MSE is an ongoing task in the new contract covering work for this stock, started in March 2022. Trial MSE runs indicated that there were no issues with the implementation of JABBA as estimator, but the procedure failed to fit the model in a number of replicates. Further work is ongoing to fine tune the behavior of this model as basis for the swordfish model-based MPs.. In order to get a first approximation of the performance of MPs based on the hockey-stick HCR for swordfish, simulations were run assuming a perfect assessment, meaning that the depletion SB/SB0 that is used in the HCR is not estimated by an assessment method, but directly observed without error from the true stock (OM). The results presented therefore do not incorporate the impact of the errors in the stock assessment, that can also have a substantial impact on the performance of the MP. Initial tests of the model indicate, however, that the bias in the estimation of depletion is fairly constant, which would be easily corrected by the tuning procedure.

Data-based

- Definition

The data-based MPs attempt to manage the fishery to achieve a target value of catch rates over a chosen CPUE series. 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: CP1) the number of years in the CPUE slope calculation, CP2) responsiveness to CPUE target deviation, CP3) responsiveness to CPUE slope and CP4) the CPUE target.

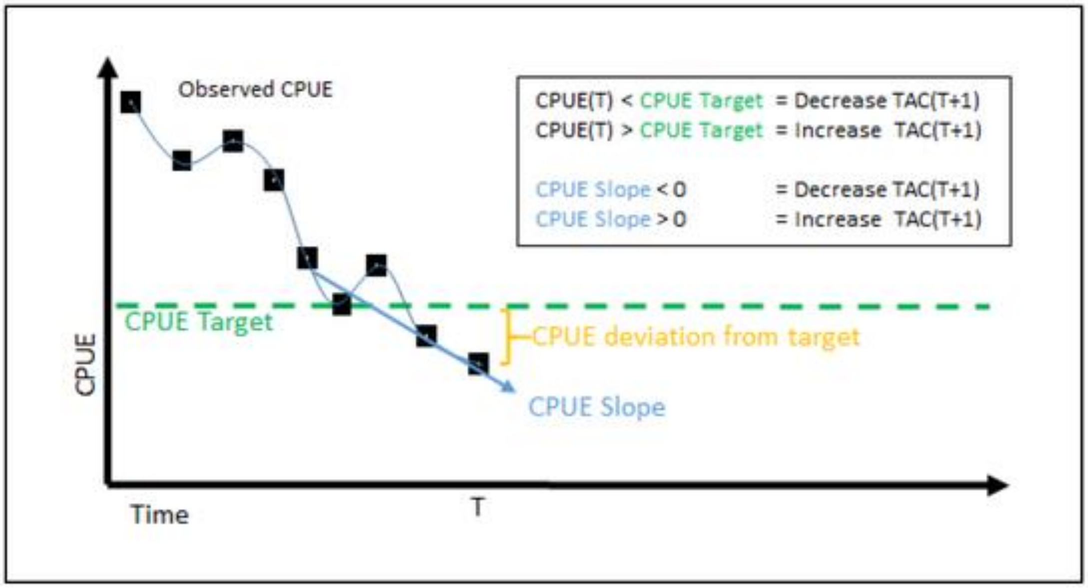

Figure 2 : illustration of the data-based MP

- Implementation in the swordfish case

The control parameters defining the responsiveness of the MP to both the current distance from the target CPUE and to the slope of the CPUE over the recent years were all set. The MP was tuned to estimate the target CPUE value for the same three management objectives as for the model based MPs.

Summary of Swordfish Candidate MP Performance

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

- The type of MP implemented (model or data based) was more important in determining some of the performance criteria (probability of being above SBlim, mean catch and inter-annual variation in the catch) than the tuning objective.

- The data-based MP led to a slightly larger average spawning biomass than the model based MPs (for a given tuning objective), but with a wider distribution of values, and consequently a higher probability of $SB<SB_{limit}$. It is expected that the implementation of an actual stock assessment in the model based MP would result in a wider distribution of spawning stock values, as the MP would then react not only changes in stock size, but also to assessment error and variability.

- The data-based MPs led to slightly lower catches, with a narrower distribution of values than the model based MPs. The inter-annual variability in the catches was however higher for the data based MPs.

- In all cases, increasing the tuning objective for P(Kobe = green) resulted in a larger stock size, reduced the probability to fall below SBlim, and led to both lower catches and inter-annual catch variability.

Tuning objectives are achieved (mean P(Kobe=green) at 0.5, 0.6 or 0.7) but there is a large variability in this probability between simulation iterations (i.e. the 25^{th}-75^{th} quantile interval ranges from 0 to 1). This is explained by the fact that the choices made when assembling the OM (i.e. the grid of stock assessment assumptions used) resulted in a very wide range of stock dynamics and initial stock status. Most of the simulations start in the red (or green) quadrant of the Kobe plot, and remain in the same quadrant throughout the simulation period, despite the implementation of a MP. The tuning procedure is able to achieve its objective by finding a MP that modifies the proportion of the simulations that change quadrant on the Kobe plot (and thereby affects the mean P(Kobe=green)). However, most of the simulation iterations have a probability of either 0 or 1, and only a small fraction have a value close to the tuning objective.

These findings call for a review of the basis for this OM, to be carried out for presentation to and revision by WPM in October 2022.

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) The developers would welcome any feedback on the 2 types of MPs proposed, and would like to know if the commission request them to test alternatives MPs.

2) Are the tuning objectives agreed up on in previous TCMPs still considered relevant?

3) In the hockey-stick HRC, should there be a minimum catch allowed when depletion rate is below CT1, to take into account, for example, subsistence fisheries, and if so, what should be the basis to set this minimum catch.

4) Could the simulation be carried out assuming that the 3 year total lag mentioned in TCMP04 (2021), could turn into a two year lag, if any adopted MP is to have direct application, as it is the case for the skipjack current HCR?

Table 1: performance of candidate MPs with respect to key performance measures (averaged over the period 2034-2039).

MP	prob(SB>SB_{limit})	Catch Variability	prob(Green)	Mean Catch	SB/SB_{MSY}
MP1	>0.99	5.3	0.51	29874.0 (23380.1-34802)	1.1 (0.2-3)
MP2	>0.99	4.5	0.60	26782.4 (22260.5-31179)	1.3 (0.3-3)
MP3	>0.99	4.2	0.70	22503.1 (19175.2-26392)	1.5 (0.6-3)
MP4	>0.99	3.8	0.49	29869.5 (18518.4-45759)	1.1 (0.5-2)
MP5	>0.99	3.5	0.58	29014.4 (17937.3-41833)	1.2 (0.6-2)
MP6	>0.99	3.2	0.69	28196.5 (17554.1-37500)	1.4 (0.7-3)

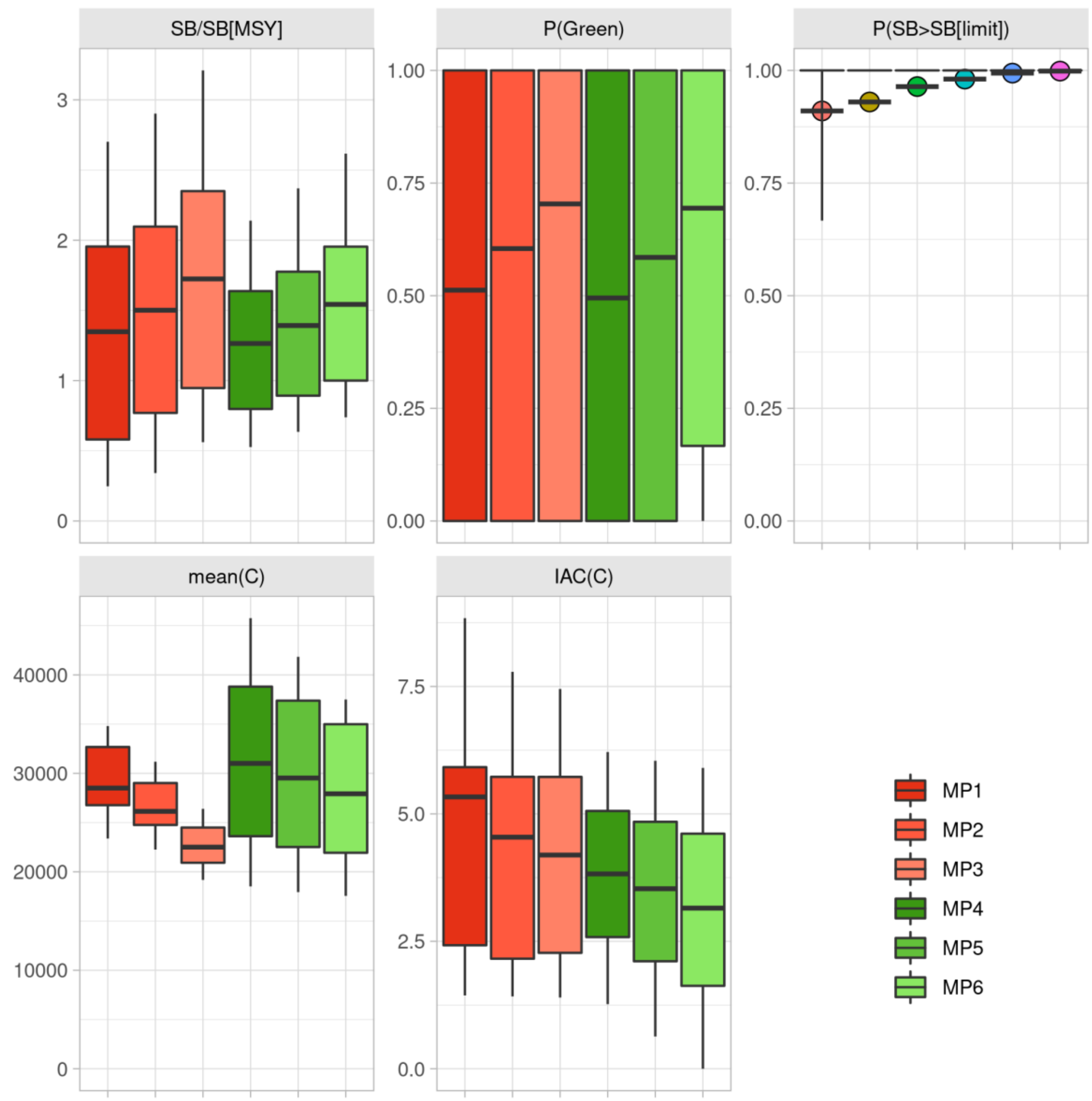

Figure 3. Boxplots comparing candidate MPs with respect to key performance measures averaged over the period 2034-2039. Horizontal line is the mean, boxes represent 25th - 75th percentiles, thin lines represent 10th - 90th percentiles. The data based MPs are depicted in red and model-based MPs are depicted in Green

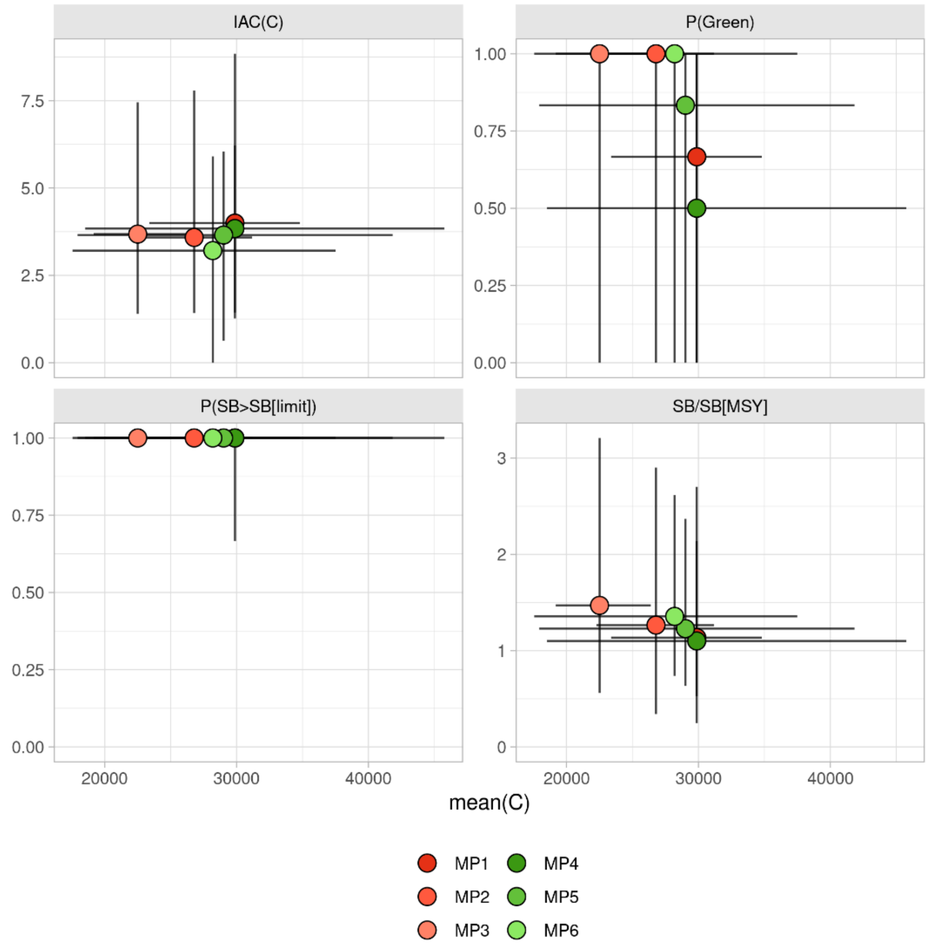

Figure 4. Trade-off plots comparing candidate MPs with respect to catch on the X-axis, and 4 other key performance measures on the Y-axis, each averaged over the period 2034-39. Circle is the median, lines represent 10th-90th percentiles..

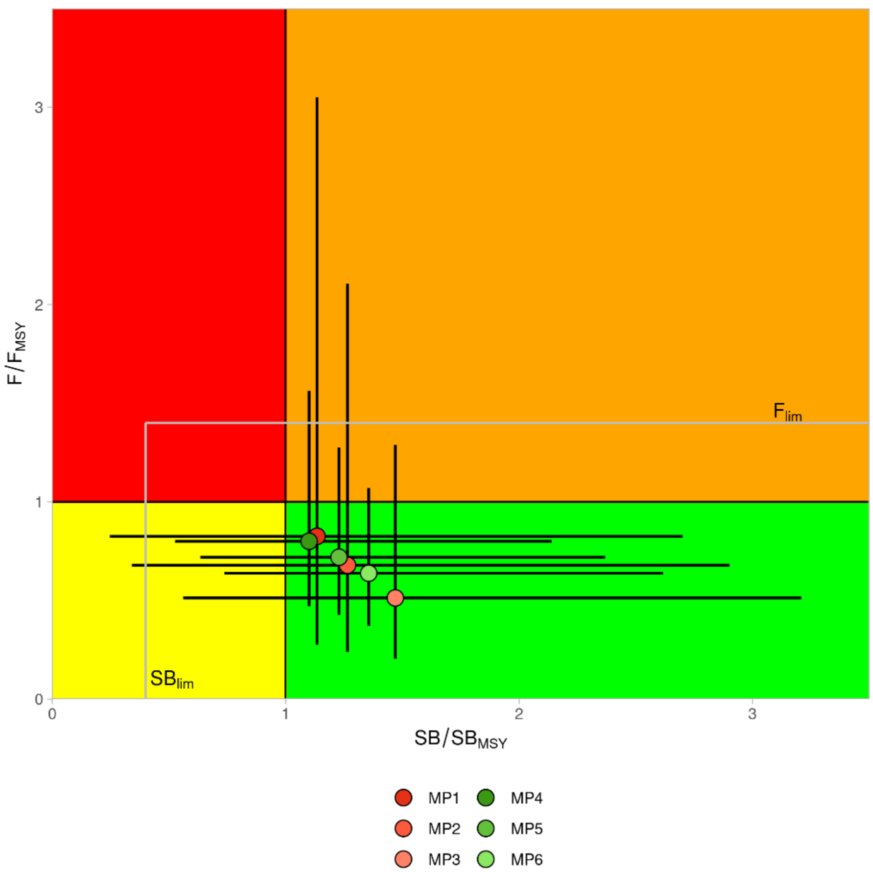

Figure 5. Kobe plot comparing candidate MPs on the basis of the expected 2034-2039 average performance. Circle is the median, lines represent 10th-90th percentiles.

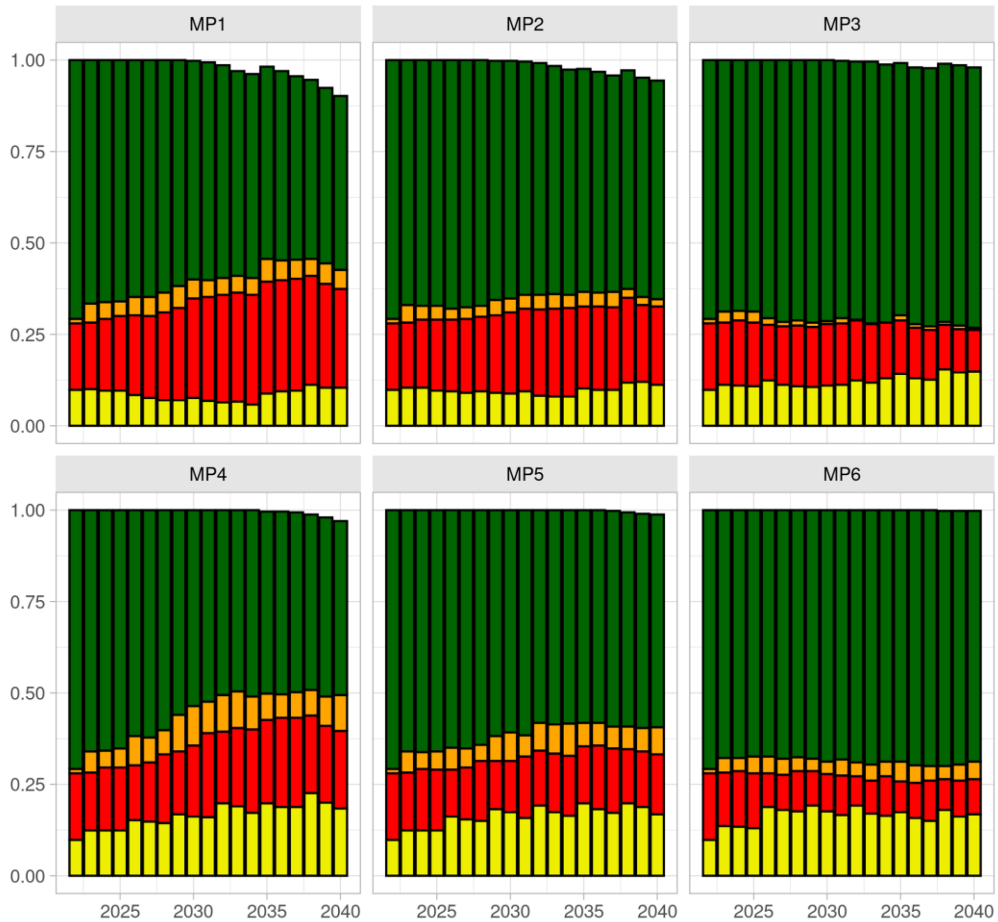

Figure 6. Proportion of simulations in each of the Kobe quadrants over time for each of the candidate MPs.

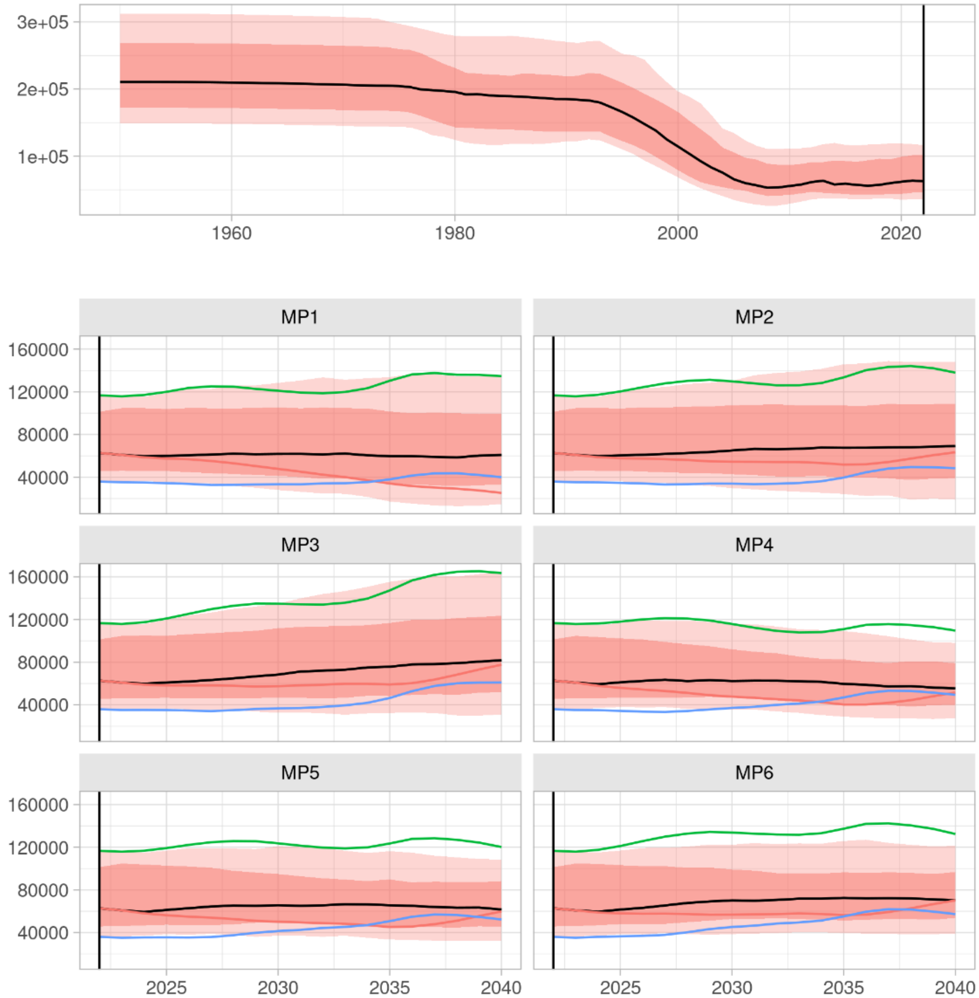

Figure 7. Time series of spawning stock size for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The median is represented by the bold black line, the darker red shaded ribbon represents the 25th-75th percentiles, the lighter red shaded ribbon represents the 10th-90th percentiles. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate the range of expected realizations in stock trajectory.

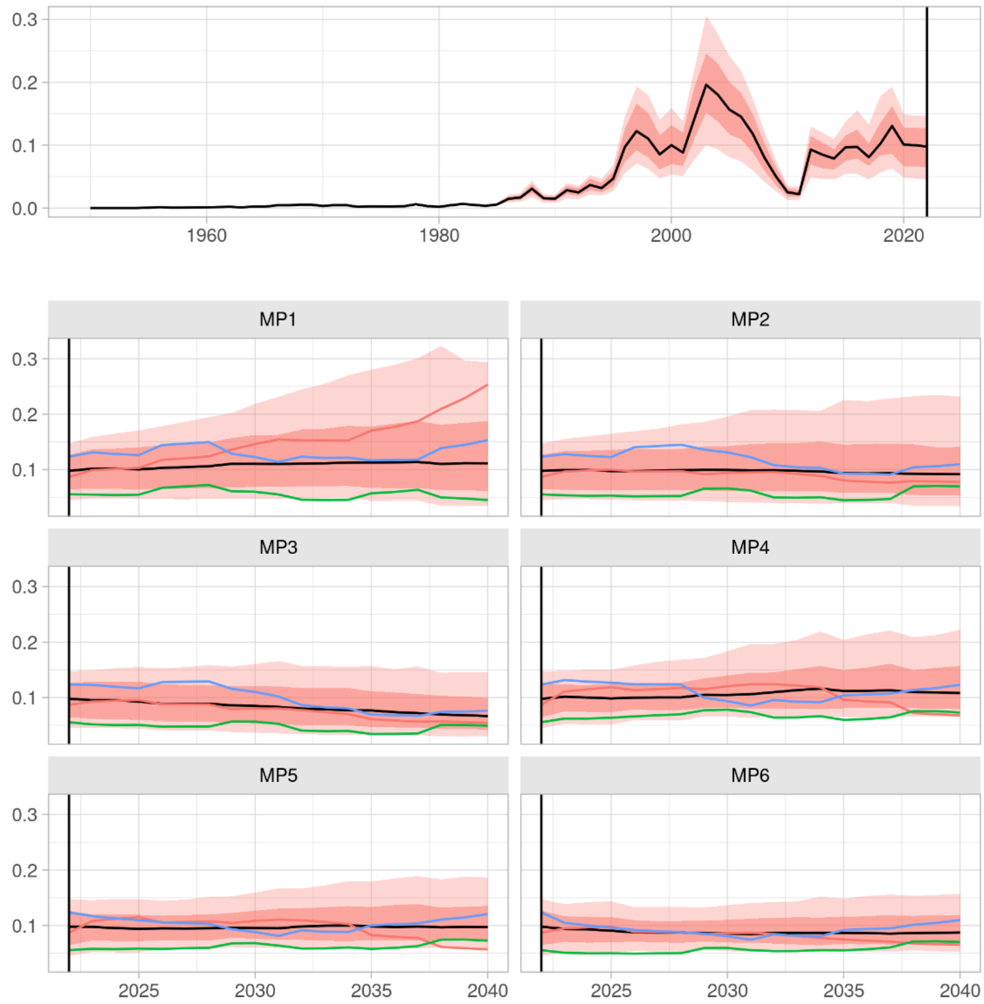

Figure 8. Time series of fishing intensity for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The median is represented by the bold black line, the darker red shaded ribbon represents the 25th-75th percentiles, the lighter red shaded ribbon represents the 10th-90th percentiles. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate the range of expected realizations in stock trajectory.

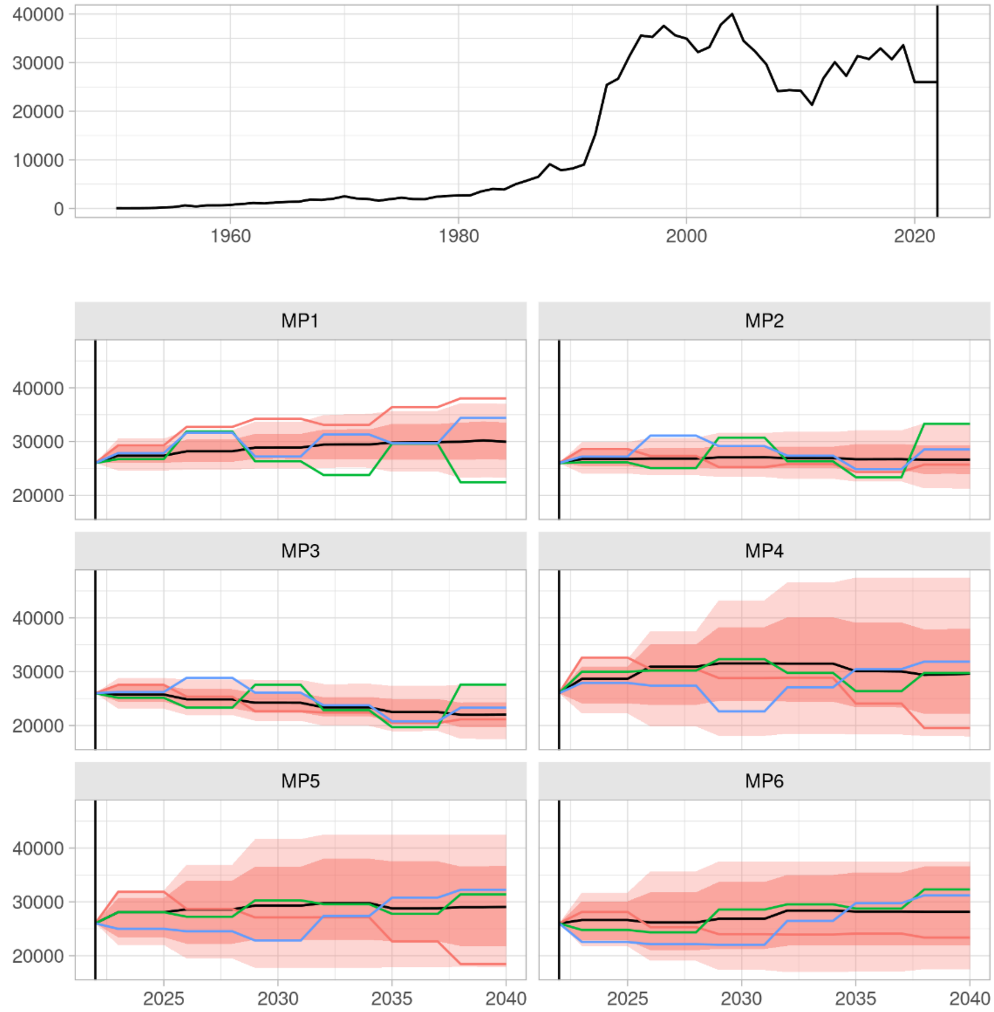

Figure 9. Time series of catch for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The median is represented by the bold black line, the darker red shaded ribbon represents the 25th-75th percentiles, the lighter red shaded ribbon represents the 10th-90th percentiles. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate the range of expected realizations in stock trajectory.

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 2022-2026.

Performance metrics	name	MP1	MP2	MP3	MP4	MP5	MP6
Mean catch over years	mean(C)	27410	26770	25780	27822	27260	26453
Mean fishing mortality relative to FMSY	F/FMSY	0.77	0.75	0.72	0.75	0.73	0.7
Mean fishing mortality relative to target	F/Ftarget	0.77	0.75	0.72	0.75	0.73	0.7
Mean proportion of MSY	C/MSY	0.97	0.95	0.91	0.97	0.95	0.92
Mean spawner biomass relative to unfished	SB/SB0	0.32	0.32	0.32	0.32	0.32	0.32
Mean spawner biomass relative to SBMSY	SB/SBMSY	1.4	1.4	1.41	1.4	1.4	1.41
Minimum spawner biomass relative to unfished	min(SB/SB0)	0.3	0.3	0.3	0.3	0.3	0.3
Percentage inter-annual change in catch	IAC(C)	3.46	3.17	3.24	5.25	5.04	4.67
Probability of being in Kobe green quadrant	P(Green)	0.67	0.68	0.7	0.66	0.67	0.68
Probability of being in Kobe red quadrant	P(Red)	0.2	0.19	0.17	0.17	0.16	0.14
Probability of fishery shutdown	P(shutdown)	0	0	0	0	0	0
Probability that spawner biomass is above 20% SB[0]	P(SB > 0.20 x SB0)	0.89	0.89	0.9	0.91	0.91	0.91
Probability that spawner biomass is above SBlim	P(SB>SBlimit)	1	1	1	1	1	1

Table A1b. Candidate MP performance for standard IOTC performance measures for the year 2022-2031.

Performance metrics	name	MP1	MP2	MP3	MP4	MP5	MP6
Mean catch over years	mean(C)	28129	26972	25235	29240	28146	26739
Mean fishing mortality relative to FMSY	F/FMSY	0.86	0.81	0.72	0.79	0.74	0.69
Mean fishing mortality relative to target	F/Ftarget	0.86	0.81	0.72	0.79	0.74	0.69
Mean proportion of MSY	C/MSY	0.99	0.95	0.89	1.01	0.97	0.92
Mean spawner biomass relative to unfished	SB/SB0	0.32	0.32	0.33	0.32	0.32	0.33
Mean spawner biomass relative to SBMSY	SB/SBMSY	1.42	1.44	1.48	1.41	1.43	1.46
Minimum spawner biomass relative to unfished	min(SB/SB0)	0.24	0.24	0.23	0.27	0.28	0.29

Percentage inter-annual change in catch	IAC(C)	2.74	2.55	2.66	3.76	3.61	3.33
Probability of being in Kobe green quadrant	P(Green)	0.64	0.67	0.7	0.61	0.65	0.68
Probability of being in Kobe red quadrant	P(Red)	0.23	0.2	0.17	0.18	0.15	0.12
Probability of fishery shutdown	P(shutdown)	0	0	0	0	0	0
Probability that spawner biomass is above 20% SB[0]	P(SB > 0.20 x SB0)	0.85	0.86	0.88	0.9	0.91	0.91
Probability that spawner biomass is above SBlim	P(SB>SBlimit)	1	1	1	1	1	1

Table A1c. Candidate MP performance for standard IOTC performance measures for the year 2022-2041.

Performance metrics	**name**	**MP1**	**MP2**	**MP3**	**MP4**	**MP5**	**MP6**
Mean catch over years	mean(C)	28578	26792	24081	30160	28833	27287
Mean fishing mortality relative to FMSY	F/FMSY	1.08	0.94	0.73	0.89	0.78	0.69
Mean fishing mortality relative to target	F/Ftarget	1.08	0.94	0.73	0.89	0.78	0.69
Mean proportion of MSY	C/MSY	1	0.94	0.85	1.03	0.99	0.93
Mean spawner biomass relative to unfished	SB/SB0	0.31	0.33	0.35	0.3	0.32	0.34
Mean spawner biomass relative to SBMSY	SB/SBMSY	1.4	1.47	1.59	1.35	1.42	1.5
Minimum spawner biomass relative to unfished	min(SB/SB0)	0.24	0.24	0.23	0.27	0.28	0.29
Percentage inter-annual change in catch	IAC(C)	3.56	3.27	3.29	3.75	3.52	3.22
Probability of being in Kobe green quadrant	P(Green)	0.59	0.64	0.71	0.56	0.62	0.69
Probability of being in Kobe red quadrant	P(Red)	0.26	0.21	0.15	0.2	0.16	0.11
Probability of fishery shutdown	P(shutdown)	0.02	0.01	0	0	0	0
Probability that spawner biomass is above 20% SB[0]	P(SB > 0.20 x SB0)	0.77	0.81	0.86	0.84	0.88	0.92
Probability that spawner biomass is above SBlim	P(SB>SBlimit)	0.97	0.98	0.99	0.99	1	1