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Update of Indian Ocean Bigeye Tuna MSE

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1 Abstract

This paper is an update of the Indian Ocean Bigeye Tuna Management Strategy Evaluation work. Given the recommendations of both the 2021 WPTT and Scientific Committee, we tuned the reduced set of two candidate MPs to the B2 and B3 risk criteria, with the tuning years now being defined as 2034-2038. Updated catch estimates were used to generate the 3-year average that is used to define catches taken between the last year of reported catch data and prior to the 2023 implementation of the MPs. The most influential robustness trials from the previous work (recruitment shock, longline catchability trend) were also useful for outlining the contrasts between the two candidate MPs and two tuning risk criteria combinations. As in previous evaluations, the largest differences in performance are between the tuning risk criteria. Results are very comparable to the previous suite of runs, with only very minor changes to early catch trajectories given the required extension of the tuning period.

2 Background

The bigeye OM has changed very little since 2019. The SC endorsed the OM and agreed that no further reconditioning of the OM was required (the 'Butterworth guillotine'). In 2021 Kolody and Jumppanen introduced a new MP (PTBoB0Targ, Figure 1) that combined the state-space Pella-Tomlinson production model with a constant catch projection designed to mimic the key features of the Kobe strategy matrix K2SM (Kolody & Jumppanen, 2021). The addition of this MP appeared to lower catch variation while maintaining the required performance in terms of attaining the key biomass objectives. As agreed at SC 2021, the suite of candidate MPs has been reduced to two, with both utilising the state-space Pella-Tomlinson production model; one uses a fishing mortality-SSB depletion hockey-stick HCR (PT41F), and the other is the previously defined K2SM projection type (PTBoB0Targ).

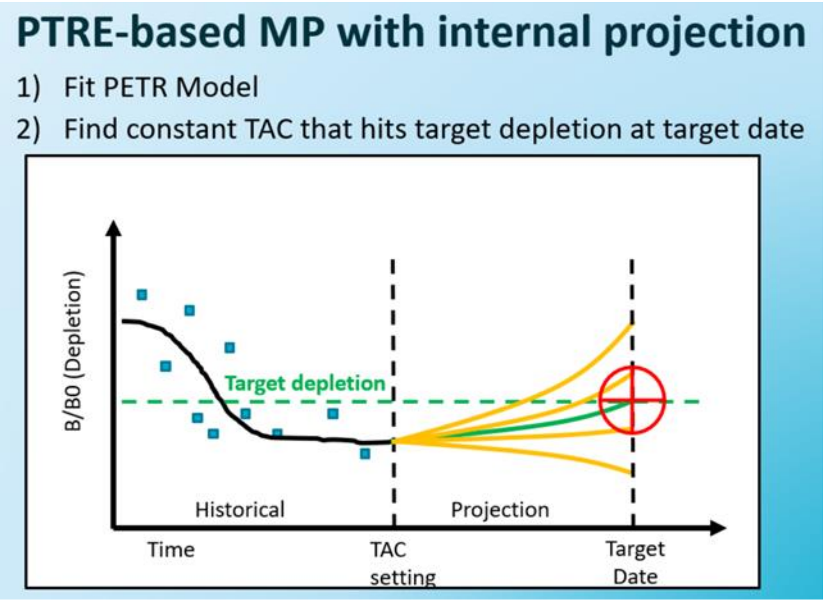

Figure 1: Schematic of the PTBoB0Targ candidate MP introduced in 2021.

In 2021 the Commission agreed to consider two tuning criteria, and both candidate MPs have been tuned to the B2 (probability of being in the Kobe 'green zone' of 0.6 during the tuning period) and B3 (probability of being in the Kobe 'green zone' of 0.7 during the tuning period). For both candidate MPs a (symmetric) maximum TAC change of 15% was applied. The tuning period was altered to be 2034-2038 given 2023 as the first MP implementation year, and the condition for the tuning period to be 11-15 years from MP implementation. This yielded four combinations of the two candidate MPs and two tuning objectives, and all of these tuned MPs were run on the previously agreed key robustness trials (Kolody & Jumppanen, 2021). Constant catch MPs were not considered for comparative tuning given it has been repeatedly demonstrated that they clearly underperform relative to any of the candidate full-feedback MPs that have previously been explored (Kolody & Jumppanen, 2021). Both candidate MPs use only the following data inputs:

1. Total catches (1980-2018)

2. The standardised longline CPUE series (1980-2018)

3 Results

For both candidate MPs, a robust bisection tuning algorithm was used to estimate the value of the tuning parameter. A log-scale tuning tolerance of 0.01 was used, which defines to an effective 1% tuning tolerance in real space for the tuning risk targets. For the PTF1F MP, the tuning parameter is the fishing mortality multiplier (relative to the estimate F_{msy}); for the PTBoB0Targ MP, the tuning parameter is the target biomass depletion.

Figure 2 plots the general time-averaged summary of CMP performance:

- SSB performance is very similar, with both CMPs showing negligible risk of breaching the limit reference point
- Average catches are slightly higher for PTF1F relative to PTBoB0Targ but so is catch variability and it also has a lower tail in the catch distribution (lowest catches are lowest for PTF1F).

Tables 1 and 2 detail the high level and more detailed time-averaged (20 years) summary statistics, respectively. Figures 3 and 4 summarise the Kobe probability characteristics of the CMPs. In the time varying case (Figure 3), both are very similar up to about 2030, but afterwards the probability of re-entering the orange and red zones begins to rise more rapidly for the PTF1F CMP given it begins to increase catches more in this period, relative to PTBoB0Targ. Overall Kobe performance is very similar between MPs (Figure 4), with the tuning objective making far more difference than the MP structure. Due to higher catches in the middle of the projection period PTF1F appears to be going to undershoot/overshoot the biomass/fishing mortality MSY targets, whereas PTBoB0Targ appears to be approaching stochastic equilibrium more monotonically.

From Figure 5, short term catch performance (i.e. first two TAC periods) differs most for the B2 tuning objective. CMP PTF1F shows a tendency for median catches to be below the recent three-year 85.6 kt average (2018-2020) for the first two TAC decision periods; for PTBoB0Targ the median TAC for the first period is slightly lower than the recent average, and for the second TAC period it is basically the same. For both CMPs and tuning criteria, median TACs are above the recent three-year average by 2030 and stay above this level, reaching a plateau at around 110-120 kt. SSB relative to MSY dynamics are very similar between CMPs for the same tuning criteria. Fishing mortality relative to MSY is also very similar between CMPs for the same tuning, but by the last decade of the projections the probability of being both above MSY target and limit levels is increasingly higher for PTF1F, relative to PTBoB0Targ.

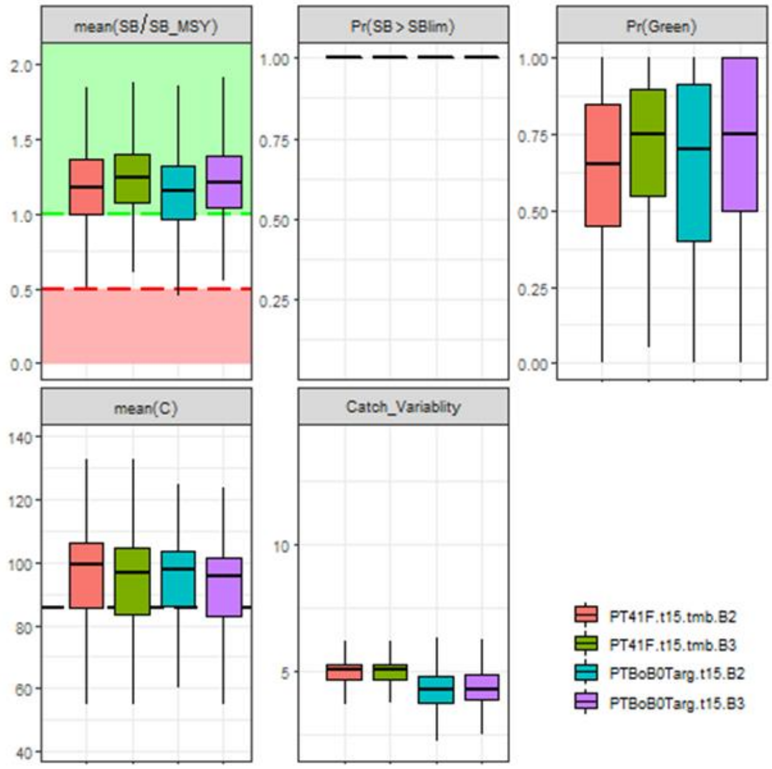

Figure 2: Boxplots comparing candidate MPs (tuned to B2 and B3) with respect to key performance measures averaged over 20 years. Horizontal line is the median, boxes represent 25th - 75th percentiles, thin lines represent 10th - 90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB$_{MSY}$ performance measure. The horizontal dashed black line is the 2018-2020 average catch.

	Performance Measure				
Management Procedure	SB/SB$_{MSY}$	Prob(Green)	Prob(SB>limit)	Mean Catch	Catch Variability
A.B2	1.18 (1.00-1.36)	0.63	0.97	99.3 (85.6-106.1)	5.06
B.B2	1.15 (0.96-1.32)	0.63	0.97	97.7 (86.0-103.6)	4.23
A.B3	1.24 (1.07-1.40)	0.69	0.98	96.6 (83.7-104.6)	5.08
B.B3	1.21 (1.04-1.39)	0.69	0.98	95.8 (82.8-101.6)	4.28

Table 1: High level summary for table PT41F (A) and PTBoB0Targ (B) tuned to the B2 and B3 tuning criteria. A 20 year averaging period was used to create these statistics.

Status : maximise stock status		**20 year average**			
		A.B2	**B.B2**	**A.B3**	**B.B3**
Mean spawner biomass relative to pristine	SB/SB_0	0.32	0.30	0.34	0.33
Minimum spawner biomass relative to pristine	SB/SB_0	0.21	0.22	0.22	0.23
Mean spawner biomass relative to SBMSY	SB/SB_{MSY}	1.18	1.15	1.24	1.21
Mean fishing mortality relative to FMSY	F/F_{tar}	0.82	0.82	0.78	0.76
Mean fishing mortality relative to target	F/F_{MSY}	0.82	0.82	0.78	0.76
Probability of being in Kobe green quadrant	SB,F	0.63	0.63	0.69	0.69
Probability of being in Kobe red quadrant	SB,F	0.21	0.22	0.16	0.16
Safety : maximise the probability of remaining above low stock status (i.e. minimise risk)					
Probability of spawner biomass being above 20% of SB0	SB	0.87	0.87	0.90	0.91
Probability of spawner biomass being above BLim	SB	0.97	0.97	0.98	0.98
Yield : maximise catches across regions and gears					
Mean catch (1000 t)	C	99.35	97.69	96.57	95.81
Mean relative CPUE (aggregate)	C	0.83	0.82	0.81	0.79
Mean catch relative to MSY	C/MSY	1.10	1.07	1.15	1.14
Stability: maximise stability in catches to reduce commercial uncertainty					
Mean absolute proportional change in catch	C	5.06	4.23	5.08	4.28
% Catch coefficient of variation	C	0.20	0.16	0.22	0.17
Probability of shutdown	C	0.00	0.00	0.00	0.00

Table 2: Detailed summary for table PT41F (A) and PTBoB0Targ (B) tuned to the B2 and B3 tuning criteria. A 20 year averaging period was used to create these statistics.

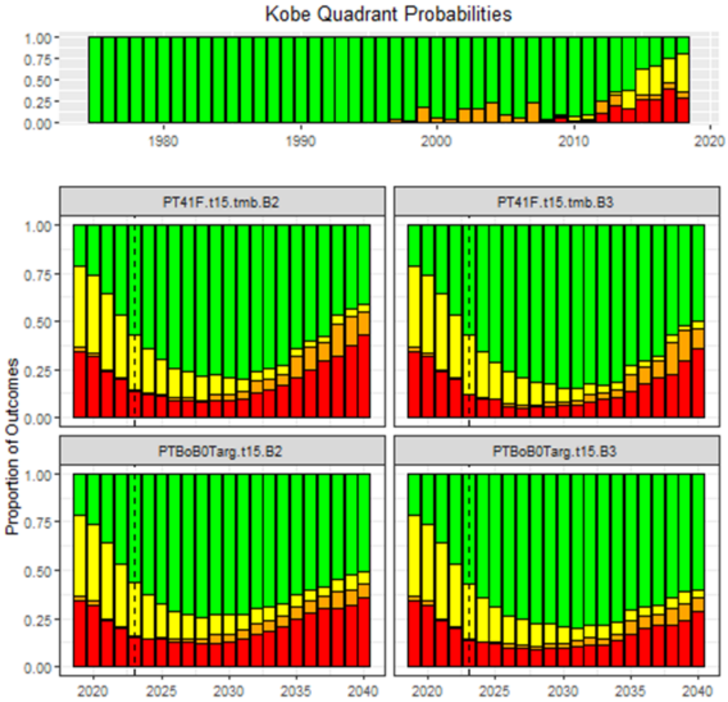

Figure 3: Proportion of simulations in each of the Kobe quadrants over time for each of the candidate (tuned to B2 and B3) MPs. Historical estimates are included in the top panel. The lower panels are projections, with the first MP application indicated by the broken vertical line (2023).

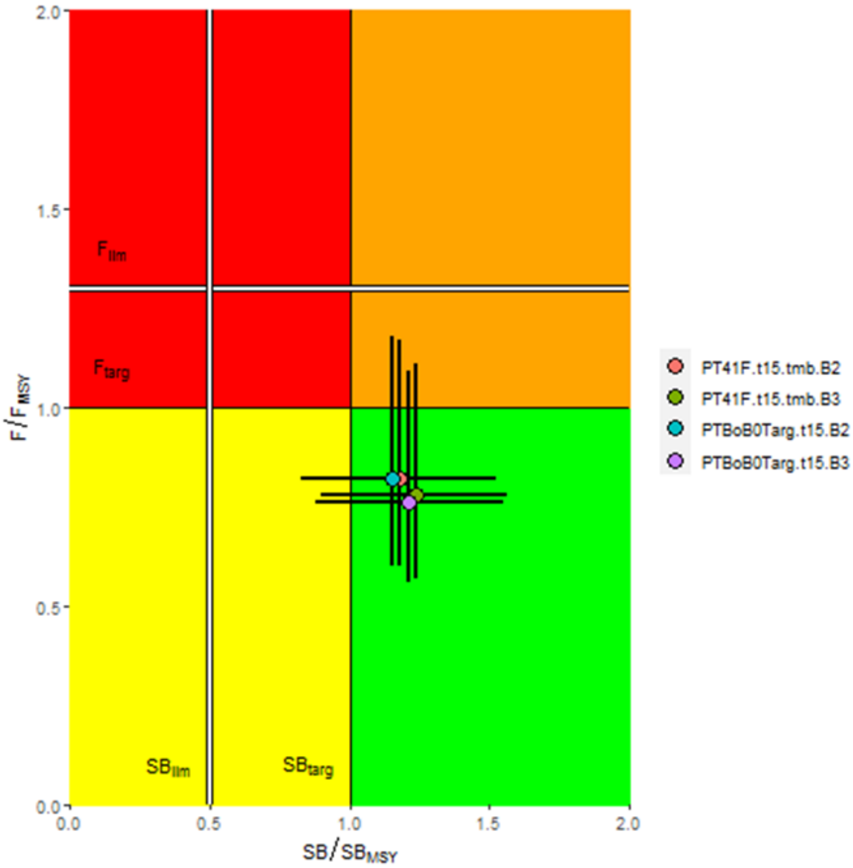

Figure 4: Time-averaged Kobe plot for the two candidate MPs tuned to the B2 and B3 tuning criteria and averaged over the first 20 years of the projection period.

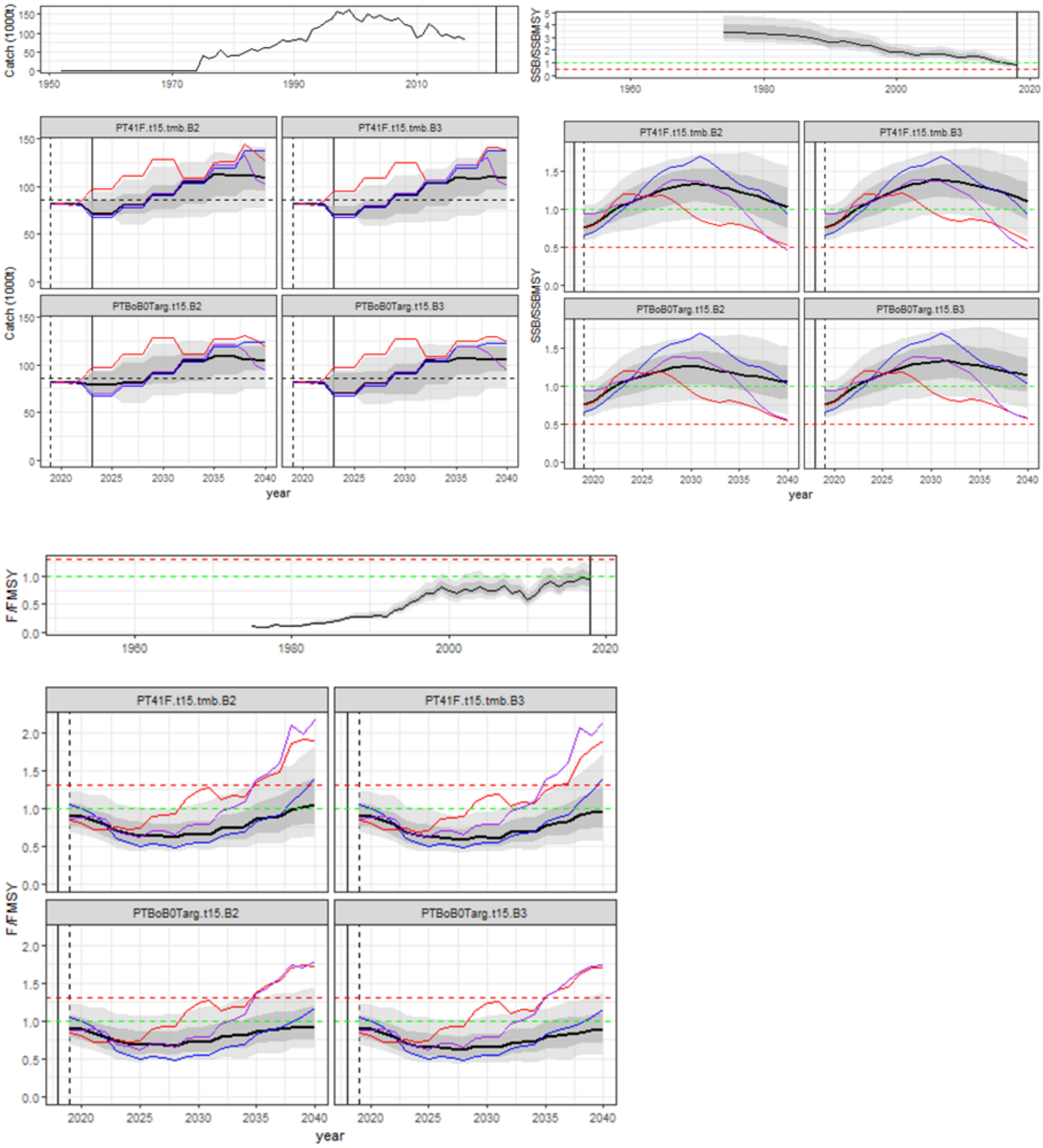

Figure 5: Time series of Catch (top left), SSBmsy ratio (top right) and Fmsy ratios (bottom) for the two candidate MPs tuned to the B2 and B3 tuning criteria. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The 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.

Robustness trials

The following robustness trials were run on both CMPs for both tuning criteria:

1. **recShock**: mean recruitment is reduced to 55% of the historical level (similar to estimates for YFT in the early 2000s) for 8 consecutive quarters following the implementation of the MP
2. **ICV30**: the information content of the projected longline CPUE is reduced (spatially aggregated annual σ_I = 0.30, auto-correlation = 0.5)
3. **10% ROC**: every fishery has a 10% over-catch implementation error, with accurate catch reporting
4. **10% IUU**: every fishery has a 10% over-catch implementation error, which is not reported
5. **qTrend3**: there is an annual 3% LL CPUE positive catchability trend starting in the projections

The only significant differences from the CMPs tuned to the reference set of OMs was for the **recShock** and **qTrend3** robustness tests. Figure 6 compares the time-dependent Kobe probabilities for PTF1F and PTBoB0Targ for the B2 tuning objective for the recruitment shock robustness test. In terms of limiting the short-term impact of the recruitment shock, PTF1F slightly outperforms PTBoB0Targ (due to more ability to reduce catch via higher TAC variability) but over the medium to longer term this reverses and PTBoB0Targ is able to continue to reduce the impact of the recruitment shock all the way through to the end of the projection period.

For the **qTrend3** robustness test, Figure 7 details the time-dependent probabilities for PTF1F and PTBoB0Targ for the B2 tuning objective. Both CMPs display a clear response to this robustness trial: the increasing bias trend in the abundance index causes catches to increase and an increase in both the orange and red Kobe probabilities after 2030. The main observable difference between the two is that PTBoB0Targ does a slightly better job of limiting the rise in the orange and red Kobe probabilities, relative to PTF1F.

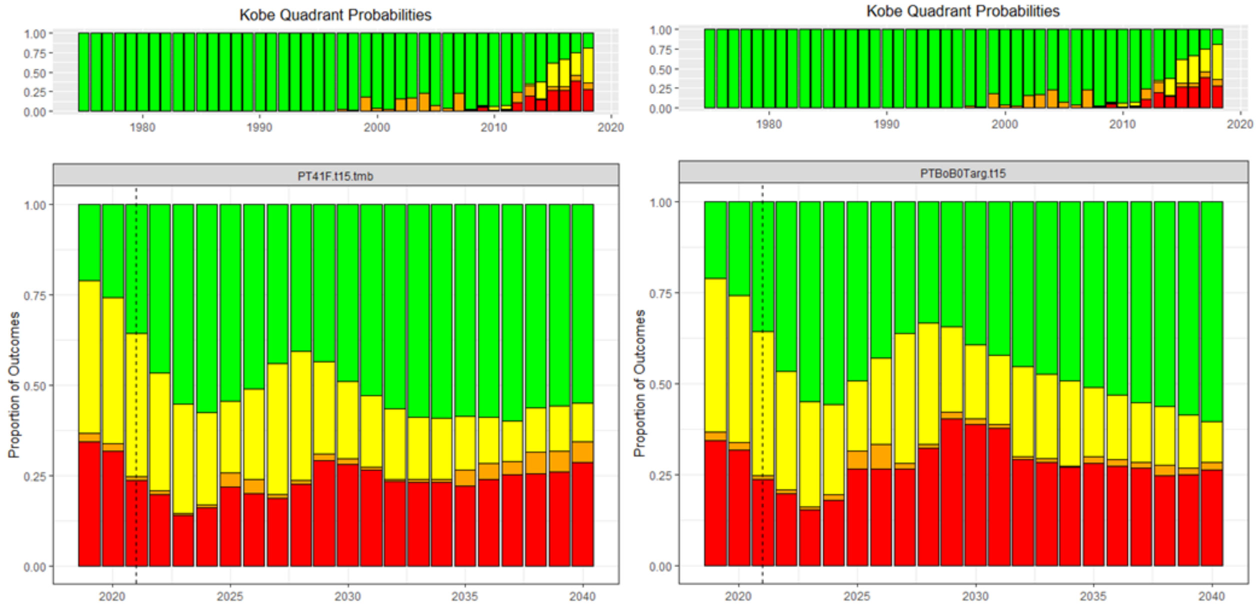

Figure 6: Time-dependent Kobe probabilities for PTF1F (left) and PTBoB0Targ (right) for the recShock robustness test.

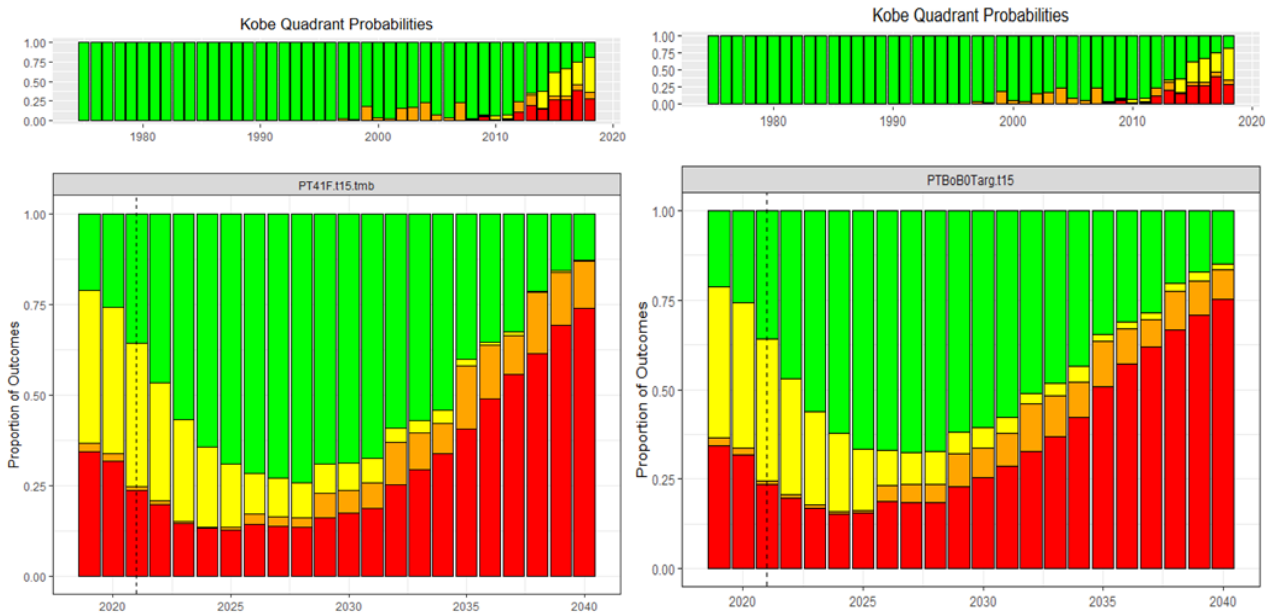

Figure 7: Time-dependent Kobe probabilities for PTF1F (left) and PTBoB0Targ (right) for the recShock robustness test.

4 Discussion

In this paper we have updated the bigeye tuna MSE to include the most recent catch biomass data (up to and including 2020), with an MP being implemented in 2023 and a tuning period from 2034-2038. The two candidate MPs agreed as the best two performing of the previous suite of options (Anon., 2021a, Anon., 2021b) were tuned to both the B2 (60% probability of being in the Kobe ‘green zone’) and B3 (70% probability of being in the Kobe ‘green zone’) tuning criteria. All four MP and tuning objective combinations were also run on the previously defined key robustness criteria. The two candidate MPs were able to tune to both the objectives and, as before, resulted in very similar overall performance. Average catches were slightly higher for the PT41F CMP, relative to PTBoB0Targ, but the latter had consistently lower TAC variability and did not appear to result in short term catch decreases (first two TAC periods), whereas PT41F did. Short-term Kobe performance was very similar, but after 2030 PTBoB0Targ resulted in a slower increase in the yellow, orange and red probabilities, relative to PT41F (this was the case for both tuning objectives). That being said, the tuning objective rather than the particular structure of the MP was the strongest differentiator of performance.

For the robustness tests the only scenarios that resulted in clearly observable performance differences were the recruitment shock and longline catchability tests. For the recruitment shock robustness test PT41F initially performed better in acting to ameliorate the low recruitment period – it’s higher level of TAC variability is actually a positive allowing it to act faster as the low recruitment signal is detected in the MP population models (which are the same). After around 2030 though PTBoB0Targ manages to consistently reduce the impact of the recruitment shock over the projection period, whereas PT41F effectively stalls and begins to worsen again after 2035. For the longline positive catchability robustness test both MPs show similar initial performance (most likely because the trend has not yet fully manifested in the MP population model estimates of biomass). However, after 2030 PTBoB0Targ displayed a slower increase in the orange and red Kobe probabilities, relative to PT41F.

Overall, both the candidate MPs tuned to the two objectives without any obvious difficulties and resulted in similar and predictable TAC and biomass/fishing mortality dynamics, with long-term average catches above the current level. Neither shows any real risk of breaching the SSB limit reference point. PTBoB0Targ outperforms PT41F, as it has both better short-term catch performance (especially for tuning objective B2) and long-term conservation outcomes (especially for fishing mortality limit reference points), when tuned to the reference set of OMs. For the robustness tests, PT41F outperforms PTBoB0Targ in the short term (which is arguably the most important period for a recruitment shock test), though less so in the longer term. For the longline catchability trend PTBoB0Targ slightly outperforms PT41F in terms of minimising the increasingly negative impact the biased abundance index has on the Kobe orange and red probabilities over time. On these key robustness tests, it would be hard to choose between both CMPs without some kind of ranking of the plausibility or risk of these robustness tests. In summation, the performance of both CMPs is certainly more than adequate, at least in terms of our experience of what tuned MPs can realistically be expected to be able to achieve. As before, by far the most influential differentiator of CMP performance is the tuning objective.

References

Anonymous (2021a) Report of the 23rd Session of IOTC Working Party on Tropical Tunas. *IOTC-21-WPTT23-R*.

Anonymous (2021b) Report of the 24th Session of the IOTC Scientific Committee. *IOTC-21-SC24-R*.

Kolody, D. and Jumppanen, P. (2021) IOTC Bigeye Tuna Management Procedure Evaluation Update. March 2021. *IOTC-2021-TCMP04-08*.

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