IOTC-2022-TCMP05-09

# Presentation of an empirical MP for Indian Ocean skipjack tuna

IOTC Technical Committee on Management Procedures

Charles T T Edwards

13 - 14 May, 2022

Eden Island, Seychelles and Online

# Background and motivation

## Overall objective

Develop a Harvest Control Rule for Indian Ocean SKJ tuna, including specification of the data inputs, that has been fully tested using a Management Strategy Simulation framework (i.e. a Management Procedure).

1. Integrate suggestions from the TCMP into the current evaluation framework;
2. Test comparability of projections conducted with FLR against SS3 simulation framework and potentially integrate into FLR;
3. Expand simulation evaluations based on feedback from the WPM (2021) and Scientific Committee (2021);
4. Propose a set of candidate Management Procedures (including the HCR and data inputs) to the TCMP (2022) for potential adoption by the Commission.

**Funded by:** Indian Ocean Tuna Commission (project MTF/INT/661/MUL).
**Time frame:** September 2021 to June 2022

# Relevant background

Background relevant to the presentation and discussion:

- **Empirical MP:** uses empirical data summaries as MP input (rather than model generated information);
- **Harvest Control Rule:** an important part of an MP;
- **Tuning of an MP:** adjust MP design to meet pre-defined objectives;
- **Robustness testing:** stress-testing of the MP to ensure it is "robust" to additional uncertainties;
- **Implementation error:** realised catch is different from the MP recommended catch;
- **Exceptional circumstances:** a formal definition of when the MP is invalidated because the system is outside of the region in which testing and development has taken place.

# Progress to date

## Simulation testing of empirical Management Procedures

A simulation framework has been developed and a set of empirical MPs have been simulation tested (Edwards, 2021a, 2021b, 2022)

- Data input generated from PL and PSLS CPUE indices;
- MPs tuned so that Pr(Kobe Green 2030 to 2034) is equal to 50%, 60% or 70% (TCMP04 recommendation, similar to BET);
- Symmetric implementation error (TCMP04 recommendation);
- Simulations indicate the familiar trade-offs between catch, stock biomass and catch stability;
- Robustness testing indicates that excessive implementation error leads to decline in performance.

Edwards, C. T. T. (2021b). Initial developments of an empirical MP for Indian Ocean Skipjack Tuna. *Research Report (IOTC–2021–TCMP04–07)*
Edwards, C. T. T. (2021a). Evaluation of empirical control rules for Indian Ocean Skipjack. *Research Report (IOTC–2021–WPM12–10)*
Edwards, C. T. T. (2022). Further evaluations of an empirical MP for Indian Ocean Skipjack Tuna. *Research Report (IOTC–2022–WPM13(MSE)–07)*

# Empirical MP for SKJ

# Harvest Control Rule

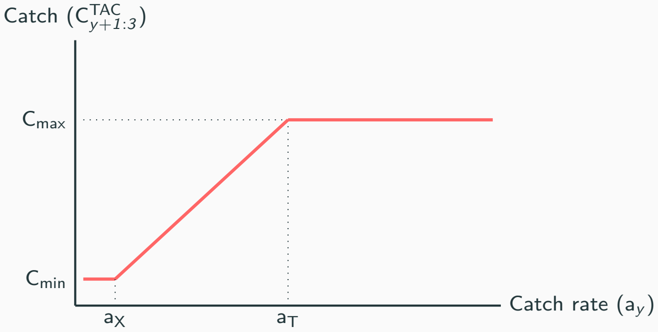
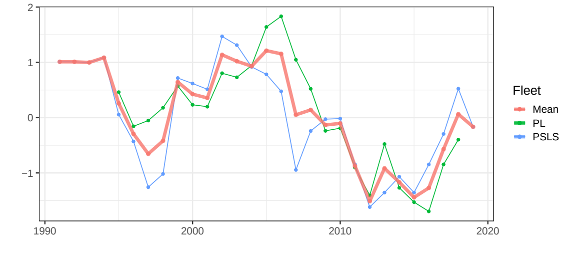



**Figure 1:** Schematic representation of the empirical Harvest Control Rule being proposed as part of the MPs. MP was tuned by adjusting $C_{max}$.

# Catch rate data

Mean of the log-normalised catch rate from:

- Maldivian Pole and Line (PL, Medley et al., 2020a, 2020b);
- European Purse Seine Log School (PSLS, Guery, 2020; Guery et al., 2020).




Close linear and positive correlation with depletion in following year. A combined catch weighted index (TCMP04 recommendation) yielded a negligible difference.

# Operating models

Based on the SKJ stock assessment of Fu, 2020; IOTC, 2020a (1950-2019) with a grid of 24 assessment runs.

- Projection over 21 year period (2020-2040 inclusive);
- Recommended catch from 2021 to 2023 set to 513,572 (IOTC, 2020b);
- Recommended TAC set for three year periods starting in 2024;
- 1 year data lag for setting the catches (i.e. CPUE data used to set the catch in the following year).

Fu, D. (2020). Preliminary Indian Ocean Skipjack Stock Assessment (Stock Synthesis). *Research Report (IOTC–2020–WPTT22(AS)–10)*

IOTC. (2020a). Report of the 22nd Session of the IOTC Working Party on Tropical Tunas, Stock Assessment Meeting. Virtual Meeting, 19 - 23 October 2020. *IOTC–2020–WPTT22(AS)–R[E] Rev1*

# Results

# Results: Tuning

| MP | $C_{min}$ | $C_{max}$ | $a_X$ | $a_T$ | Pr. Kobe Green | Tuning criteria |
|---|---|---|---|---|---|---|
| MP2 | 53.21 | 492.17 | -5.00 | -1.70 | 0.70 | Kobe 70% |
| MP4 | 53.21 | 518.77 | -5.00 | -1.70 | 0.59 | Kobe 60% |
| MP6 | 53.21 | 545.38 | -5.00 | -1.70 | 0.51 | Kobe 50% |

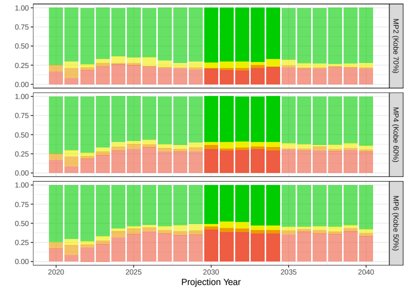



**Figure 2:** Simulated average Kobe quadrant probabilities for tuning (TCMP04 recommendation).

# Results: Overall performance

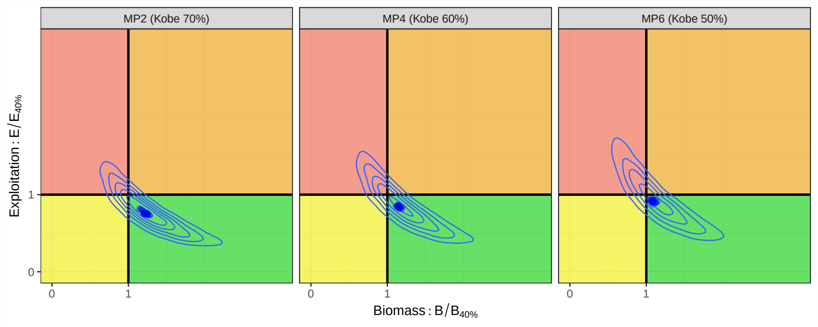



**Figure 3:** Kobe Phase plots for each MP, showing the distribution of simulated biomass and exploitation rate values between 2024 and 2040.

# Results: Overall performance

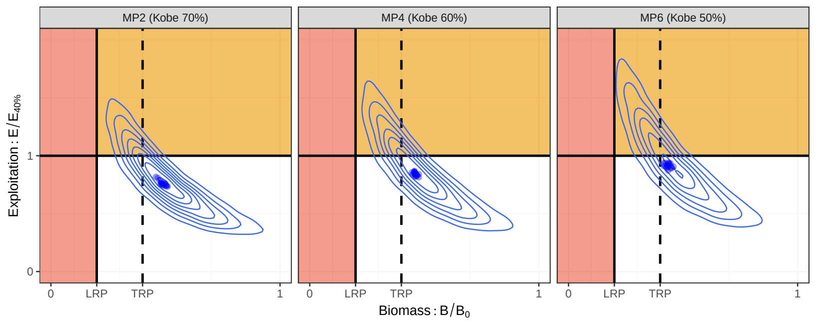



**Figure 4:** Majuro Phase plots for each MP (TCMP04 recommendation), showing the distribution of simulated biomass and exploitation rate values between 2024 and 2040. Target Reference Point = $B_{40\%}$; Limit Reference Point = $B_{20\%}$.

# Results: Absolute values

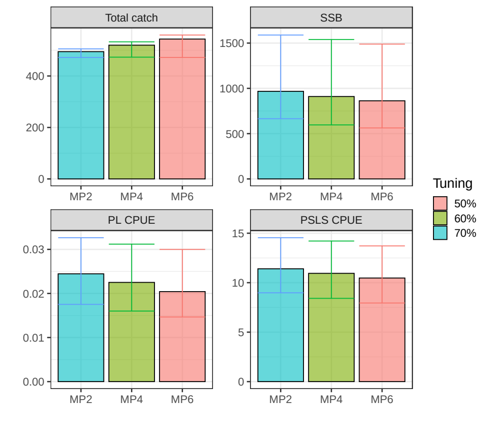



**Figure 5:** Bar plots of performance diagnostics for each MP.

# Results: trade-off plots

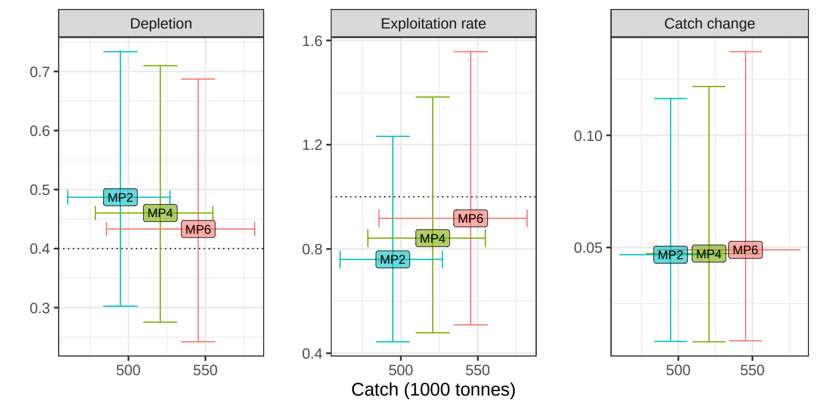



**Figure 6:** Trade-off plots for each MP.

# Results: dynamics

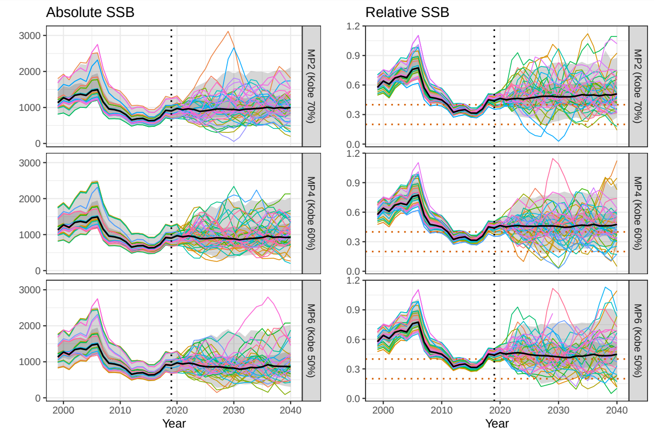



**Figure 7:** Spawning stock biomass dynamics following projection under each MP. Relative values are given according to $B_0$ for each run. Depletion reference points of 20% and 40% are shown as horizontal dashed lines.

# Results: dynamics

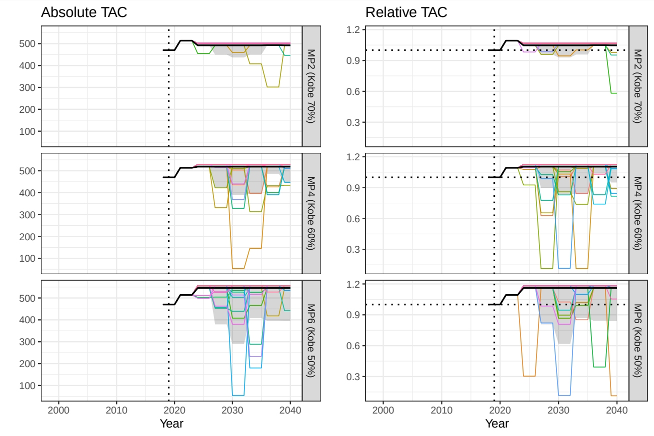



**Figure 8:** Total Allowable Catch dynamics following projection under each MP. The TAC is assumed to be 513,572 tonnes for 2021–2023. The first year of MP implementation is 2024. Relative values are given using the 2018–2020 TAC of 470,029 tonnes as a reference.

# Results: dynamics

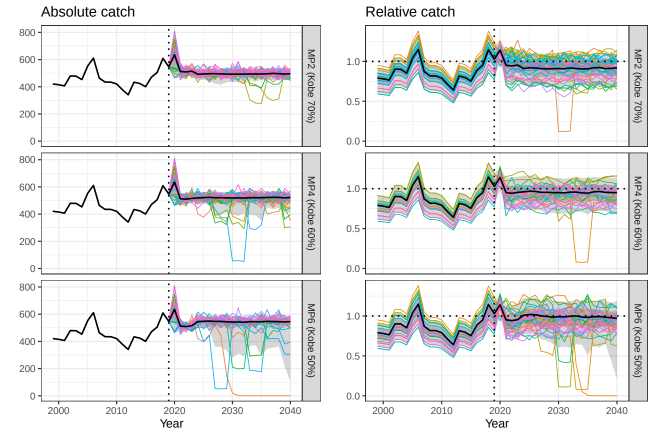



**Figure 9:** Realised catch dynamics following projection under each MP. Relative values are given according to $C_{40\%}$ for each run.

# Results

**Main result:**

This work has presented summary statistics and performance diagnostics for three MPs that passed the 50%, 60% and 70% tuning criteria. These perform well under the OM scenarios examined.

Familiar performance trade-offs between catch, catch stability and abundance.

# Robustness tests

# Robustness tests

**Implementation error**

**R01**: 20% positive catch error from 2021 to 2040;

**R02**: 30% positive catch error from 2021 to 2040;

**R03**: 40% positive catch error from 2021 to 2040;

Performance of the MPs in maintaining the stock status is undermined when catches exceed the recommended TAC.

Positive catch error can lead to a reduction in the catch over time because the stock biomass decreases.

The Kobe 70% rule is the least sensitive to positive catch error; the Kobe 50% rule is the most sensitive.

# Robustness tests

**Implementation error**

How to deal with implementation error within the MSE framework?

Two alternate approaches:

1. Agree on implementation error (e.g. 20% above the TAC) and tune MPs to be robust to that error;
2. Determine acceptable level of reduction in performance (e.g biomass 20% below expectation) and identify associated implementation error.

If implementation error exceeds the agreed error then exceptional circumstances are invoked.

# Robustness tests

**Recruitment decline**

**R01**: 50% decline from 2021 to 2023;

**R02**: 50% decline from 2022 to 2024;

**R03**: 50% decline from 2023 to 2025;

The MPs are clearly responsive to recruitment-driven changes in the stock biomass.

Able to recover the stock from extreme but short-term declines in productivity.

Provides confidence that the MPs are behaving appropriately.

# Robustness

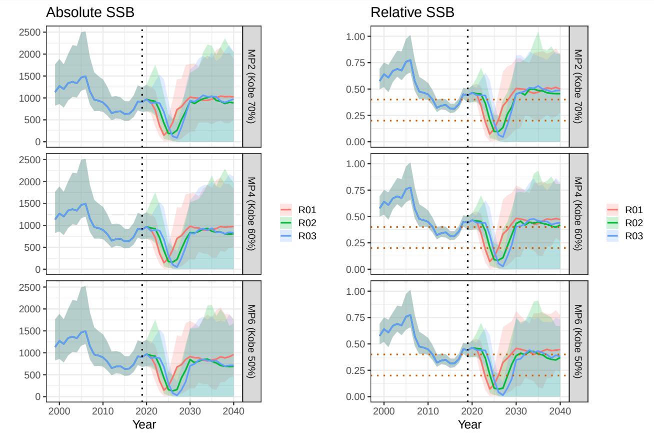



**Figure 10:** Spawning stock biomass dynamics following projection under each MP. Relative values are given according to $B_0$ for each run. Depletion reference points of 20% and 40% are shown as horizontal dashed lines.

# Robustness

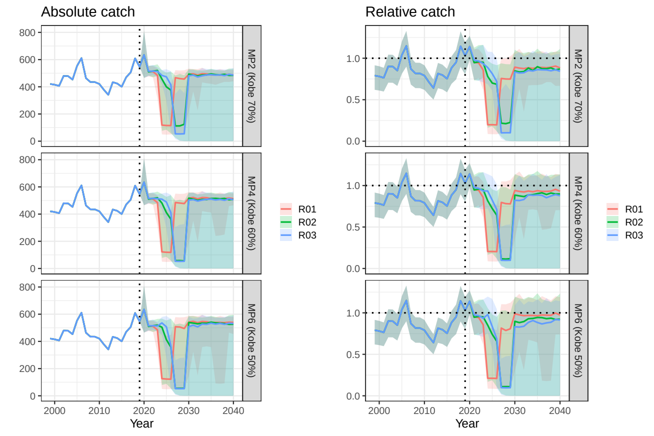



**Figure 11:** Realised catch dynamics following projection under each MP. Relative values are given according to $C_{40\%}$ for each run.

# Robustness tests

**Recruitment decline**

How to deal with recruitment decline within the MSE framework?

Changes in recruitment are difficult to measure empirically. Usually reliant on the output of stock assessment models.

One approach:

1. Agree on suitable range of recruitment fluctuation and tune MPs to be robust to that error.

If routine assessment indicates a more extreme recruitment decline then invoke exceptional circumstances.

# Conclusions

Candidate MPs have been presented that are tuned to the 50%, 60% and 70% criteria.

- Which is considered the most appropriate for setting catches?

Robustness tests provide confidence that the MPs will respond to drops in stock productivity but are sensitive to over-catch of the TAC, which will likely be detrimental to MP performance.

- In general, the more conservative MP is more robust to over-catch of the TAC.
- Should MP's be tuned to an assumed implementation error?

Performance is dependent on the consistent availability of standardised CPUE data:

- How do we ensure consistency in the data provision?
- What implementation schedule should we assume?

# Acknowledgements

I am grateful to Dan Fu (IOTC) for providing the SS III files, to Alistair Dunn (Ocean Environmental) for providing computer support and to the support of other colleagues working on MSE for IOTC (Iago Mosqueira, Richard Hillary, Ann Preece and Ashley Williams).

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# Appendices

# Results

**Table 1:** Selected diagnostic outputs for evaluation of index-based MPs.

| Diagnostic | Units | MP2 (Kobe 70%) | MP4 (Kobe 60%) | MP6 (Kobe 50%) |
|---|---|---|---|---|
| $C^{TAC}_{y+1:3}$ | $10^3$ tonnes | 492.17 | 518.77 | 545.38 |
| C | $10^3$ tonnes | 494.63 | 519.76 | 543.44 |
| $\lvert C^{TAC}_{y+1}/C^{TAC}_{y} - 1 \rvert$ | Percent | 0 (0–11) | 1 (0–16) | 1 (1–34) |
| Max. $\lvert C^{TAC}_{y+1}/C^{TAC}_{y} - 1 \rvert$ | Percent | 4 (2–32) | 3 (1–60) | 8 (6–121) |
| Pr. $\lvert C^{TAC}_{y+1}/C^{TAC}_{y} - 1 \rvert > 30\%$ | Prob. | 0.03 | 0.05 | 0.08 |
| Pr. $\lvert C^{TAC}_{y+1}/C^{TAC}_{y} - 1 \rvert > 15\%$ | Prob. | 0.05 | 0.09 | 0.11 |
| $B_y$ | $10^3$ tonnes | 967.41 | 910.06 | 862.96 |
| $B_y/B_0$ | Proportion | 0.48 | 0.44 | 0.42 |
| Pr. Kobe Green | Prob. | 0.70 | 0.61 | 0.53 |
| Pr. Majuro White | Prob. | 0.82 | 0.71 | 0.59 |

# Robustness (Implementation error)

**Table 2:** Selected diagnostic outputs for robustness to implemetation error for MP2 (Kobe 70%).

| Diagnostic | Units | MP2 | R01 | R02 | R03 |
|---|---|---|---|---|---|
| $C^{TAC}_{y+1:3}$ | $10^3$ tonnes | 492.17 | 478.69 | 458.13 | 435.51 |
| C | $10^3$ tonnes | 494.63 | 555.05 | 540.00 | 515.19 |
| $\lvert C^{TAC}_{y+1}/C^{TAC}_{y} - 1\rvert$ | Percent | 0 | 5 | 15 | 24 |
| Max. $\lvert C^{TAC}_{y+1}/C^{TAC}_{y} - 1\rvert$ | Percent | 4 | 13 | 47 | 78 |
| $B_y$ | $10^3$ tonnes | 967.41 | 844.48 | 815.54 | 763.30 |
| Pr. Kobe Green | Prob. | 0.70 | 0.46 | 0.38 | 0.34 |
| Pr. Majuro White | Prob. | 0.82 | 0.50 | 0.41 | 0.29 |

# Robustness (Implementation error)

**Table 3:** Selected diagnostic outputs for robustness to implemetation error for MP6 (Kobe 50%).

| Diagnostic | Units | MP6 | R01 | R02 | R03 |
|---|---|---|---|---|---|
| $C^{TAC}_{y+1:3}$ | $10^3$ tonnes | 545.38 | 517.77 | 482.67 | 454.86 |
| C | $10^3$ tonnes | 543.44 | 551.92 | 513.81 | 465.07 |
| $\lvert C^{TAC}_{y+1}/C^{TAC}_{y} - 1\rvert$ | Percent | 1 | 11 | 23 | 36 |
| Max. $\lvert C^{TAC}_{y+1}/C^{TAC}_{y} - 1\rvert$ | Percent | 8 | 30 | 80 | 110 |
| $B_y$ | $10^3$ tonnes | 862.96 | 758.85 | 799.84 | 745.79 |
| Pr. Kobe Green | Prob. | 0.53 | 0.35 | 0.34 | 0.30 |
| Pr. Majuro White | Prob. | 0.59 | 0.32 | 0.41 | 0.24 |