IOTC Swordfish

Management Strategy Evaluation Update

Management Strategy Evaluation Task Force of the Working Party on Methods– 10-14 April 2024

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Status of the MSE work

- The reference operating model for the Indian Ocean swordfish stock has been developed over the last four years and has been endorsed by the IOTC scientific committee. The OM was developed based on the 2020 WPB SS3 assessment, and covered the dynamics of the swordfish until the year 2018. This OM was updated to the year 2023 by projecting the stock forward based on the reported catches for the period 2019 to 2022 and assuming a fishing mortality in 2023 at the 2022 level. A comparison of the OM with the output of the new 2023 stock assessment shows that the OM remains appropriate to describe the dynamics of the Indian Ocean swordfish stock, as well as its current status.
- 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 on average) for a range of management objectives over the next 11 to 15 years.
- This performance of the tuned MPs (model-based MPs were not yet update using the latest OM) is presented in this document. The different types of MPs maintain the stock well within safe biological limits. Model-based MPs achieve very stable catches with low associated uncertainty, while the data-based MPs achieve higher but more uncertain levels of catches, with higher interannual variations.
- The robustness of the tuned MP to a systematic 10% overshoot of the catch limits was tested. All MPs appear to be robust to such an implementation error (no increase in the risk of SB falling below B_{lim}).

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- Further work involves tuning the model-based MPs using the latest version of the OM and conducting an additional robustness test (15% overshoot during the three years of the simulations).

Operating model development

Basis for the OM

The basis for the current swordfish OM was presented at the 2023 TCMP, and both at the 2023 Working party on Billfish and 2023 Working party on Methods. The working document presented at TCMP (IOTC 2023) included a revision of the OM grid that decreased the number of factors considered, by identifying those having little impact on initial stock status and productivity in the OM. This resulted in a new grid containing 648 combinations, of which 175 were selected by factorial design optimization (vs 2592 and 108 respectively for the earlier OM). The SS3 stock assessment was run for these 175 parameter combinations, and 130 runs were ultimately considered acceptable (based on model convergence, biomass index prediction skill, and credibility of B0 estimates) and used as a basis for the OM (vs 67 for the original OM).

The basis for the OM are SS3 runs based on the 2020 stock assessment for the Indian ocean swordfish stock, that covered the development of the stock until the year 2018. In order to conduct simulations starting with a stock status as close as possible to the current status, the OM was projected forward over the years 2019-2023 using the IOTC catch estimates for the years 2019 to 2022, and assuming a status quo fishing mortality for 2023 ($F_{2023}=F_{2022}$).

Comparison with the latest swordfish assessment

During WPB 2023 an updated SS3 assessment was presented. It consists of an ensemble of 47 SS3 model runs covering a grid of input parameters for the main uncertainty related to assumptions on the CPUE configuration options, stock-recruitment steepness, recruitment deviations, growth, and effective sample sizes of the length composition data. The factors and levels included are similar to the ones used to build the uncertainty grid of the swordfish OM.

<u>Stock parameters and stock status :</u>

The distribution of the population dynamics parameters from the update assessment is narrower and is generally well within the distribution of the parameters of the OM (figure 1). Likewise, the historical stock status from the 2023 assessment is comprised within the envelop of the OM (figure 2). The distribution of SB/SB_{MSY} from the assessment in its final year, 2021, is well within the OM, while the values for F/F_{MSY} are close to the limit of the envelope of the OM but still remain within it.

By definition, more sources of uncertainty are considered when building an OM for an MSE than when assembling the model runs for a stock assessment. In the case of swordfish, the structural uncertainty grid for the OM includes 7 parameters and the OM is based on 130 SS3 runs, while the grid for the assessment considers 5 parameters that lead to 48 combinations.

Overall, the new 2023 assessment does not drastically change the perception of the dynamics and current status of the stock, and the OM build based on the previous assessment is still considered appropriate to describe the current stock status and its associated uncertainty, as well as uncertainty in the stock dynamics parameters. The OM will therefore not need to be re-conditioned.

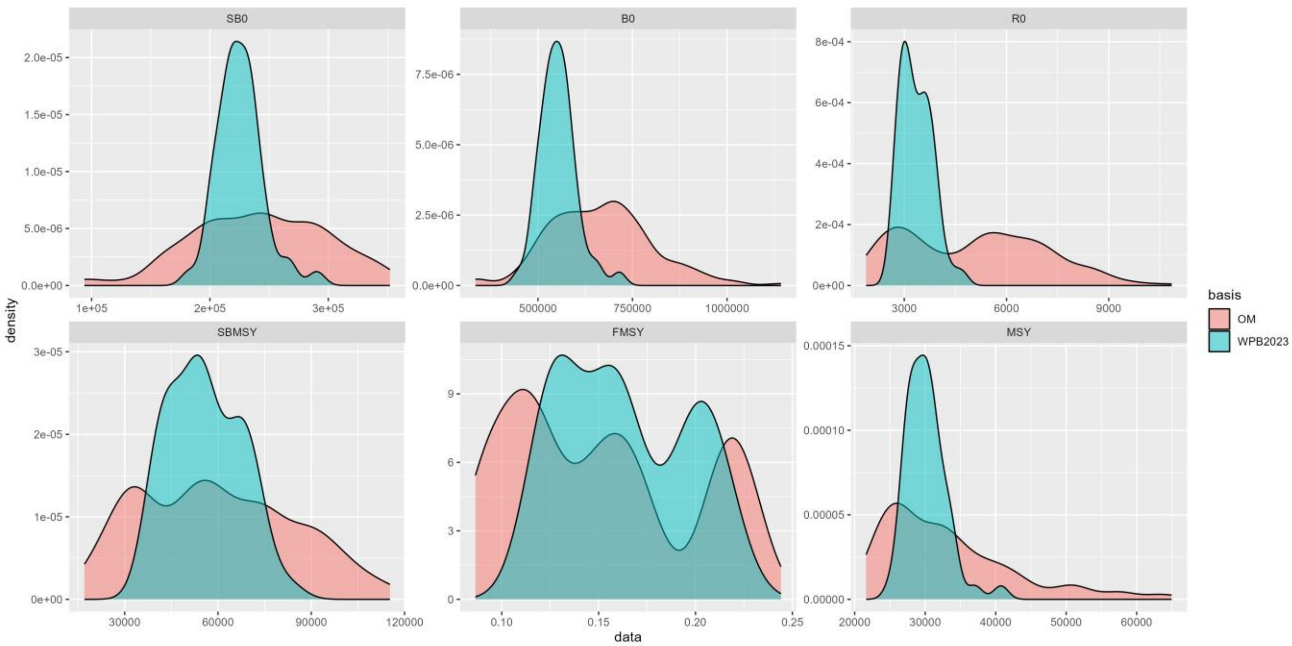

Figure 1 : Comparison of the population dynamics parameters from the WPB 2023 swordfish assessment, and from the Operating Model developed for the MSE analysis from the previous assessment.

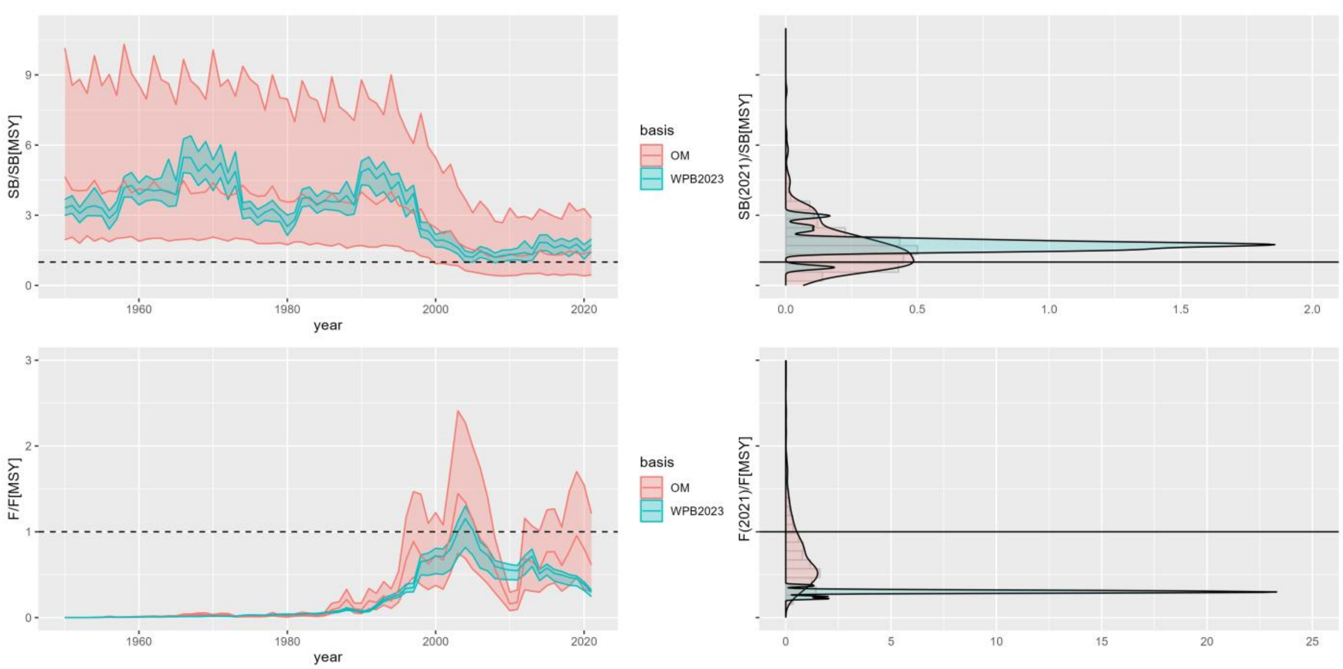

Figure 2 : Comparison of the historical development and current stock status from the WPB 2023 swordfish assessment, and from the Operating Model developed for the MSE.

Recent trends :

The 2023 assessment uses data and provides stock numbers and fishing mortality estimates until 2022. In the OM, stock numbers and fishing mortalities are obtained by projecting the 2018 stock forward until 2023. A number of assumptions are made to carry out these projections, that may depart from the actual estimates from the new stock assessment.

These assumption made when projecting the OM to cover the last years of the historical period (2019-2023) can have an impact on the stock development in the simulated period (2024 onwards).

In particular, the OM projections over 2019-2023 assumes the recruitment in this period is centred on the stock-recruitment models prediction. A comparison of the recruitment deviates shows that the deviations for OM are mainly centred on 0. This is the case both for period before 2018 where these deviations are residuals from the stock-recruitment models based on the 2020 assessment, and for the period after 2018, where the deviations are generated randomly (figure 3). The deviations for the 2023 assessment are, however, mainly positive over the period 2011 to 2018. The OM is therefore based on a wrong assumption regarding the recent recruitment productivity, which might impact the simulated stock trajectory over the short to medium term.

Likewise, the projection of the OM over the period 2019-2023 assumes that the exploitation pattern (age profile of the fishing mortality) is constant and based on the average of the last 5 years of the 2020 assessment (2014-2018). A comparison of this assumed selection pattern with the one estimated by the 2023 stock assessment shows that, according to the new assessment, the fishing mortality is still the highest for age 2 to 4, but the new assessment indicates that the older age classes (up to age 12) are more selected by the fishery compared to the assumption in the OM (figure 4). The age-groups older that 12 are also slightly less selected according to the new assessment. Such differences in the fisheries selection might have an impact on the simulated stock trajectories.

In order to explore the potential impact of these two discrepancies between the OM and the new assessment, an alternative OM was built. For each of the 500 stock replicates in the OM, the SR deviates and the selection patterns were replaced by those from one of the 47 model runs (taken randomly) in the new assessment. It should be noted that each replicate is then built based on two different model runs : one of the 130 runs derived from the2020 assessment for most of the OM and one of the 47 runs from the 2023 assessment for recruitment deviates and exploitation pattern. This means that there is an inconsistency in the basis used at the stock replicate level, but this was considered good enough to carry out a simple test.

Projecting this alternative OM forward over the simulation period imposing a constant F at F_{MSY} leads to small differences in the short term (figure 5) but the stock status at the end of the tuning period (2035) are identical in the two OMs. This indicates that the impact of the assumptions made when projecting the OM between 2019 and current year should be negligible and that the current OM can be used to the MSE.

Finally, when projecting the OM to present day, the CPUE indices for the projection period (2019-2022) are generated from the OM. These indices are used by the MP, and the recent values will have an impact on the TAC that will be set by the first iteration(s) of the MP. In reality, however, the first implementation of the MPs would be based on the latest available CPUE indices. If those are substantially different from the ones from the OM, the first TAC set in reality will differ from the ones in the simulation. To reduce this possibility, the CPUE indices in the observation error model (OEM) were updated, using the indices used as input in the 2023 stock assessment (available until 2022).

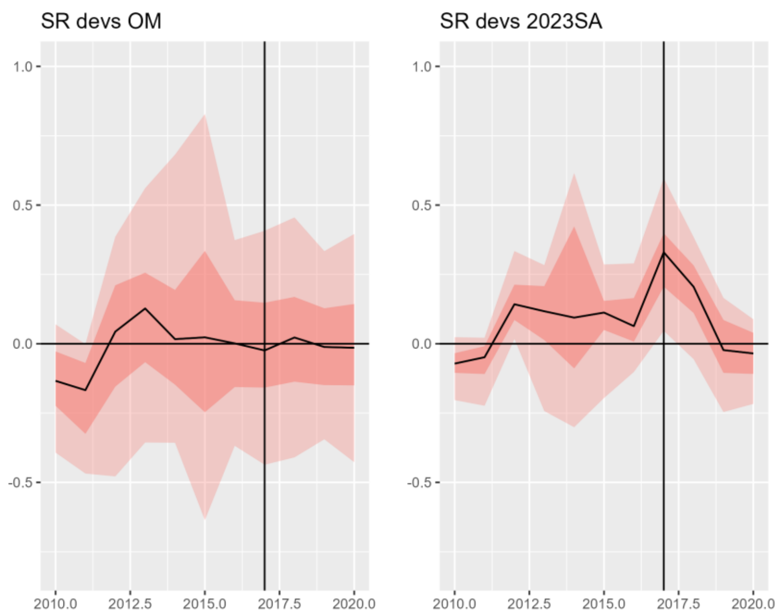

Figure 3 : Comparison of the deviations from the stock-recruitment models for the OM ("SR devs OM") and for the 2023 swordfish assessment ("SR devs 2023SA"). The vertical line in 2018 separates the period over which the OM is based on the 2020 assessment, from the period over which the OM is projected.

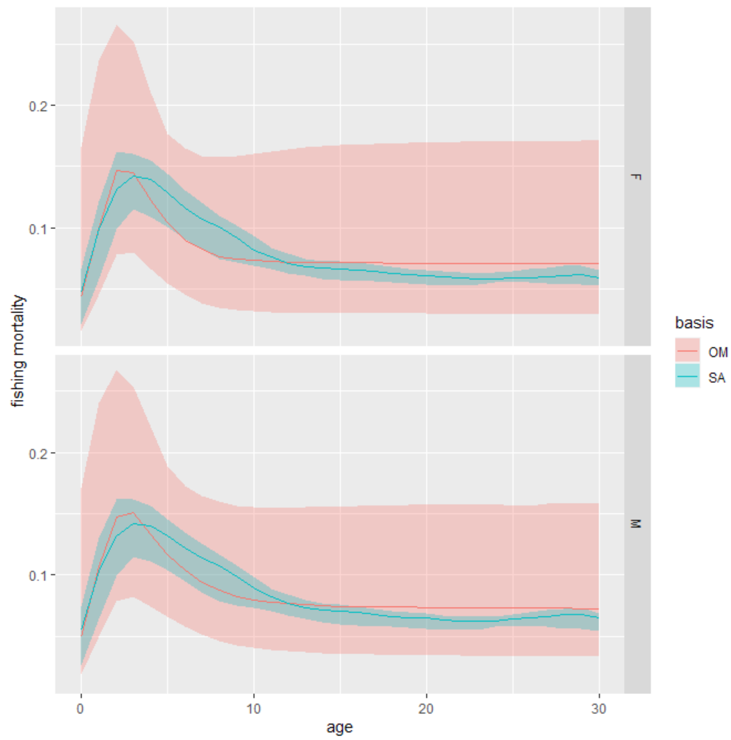

Figure 4 : average fishing morality-at-age for males and females over the recent years (2018-2021) from the operating model (OM) and from the 2023 stock assessment (SA).

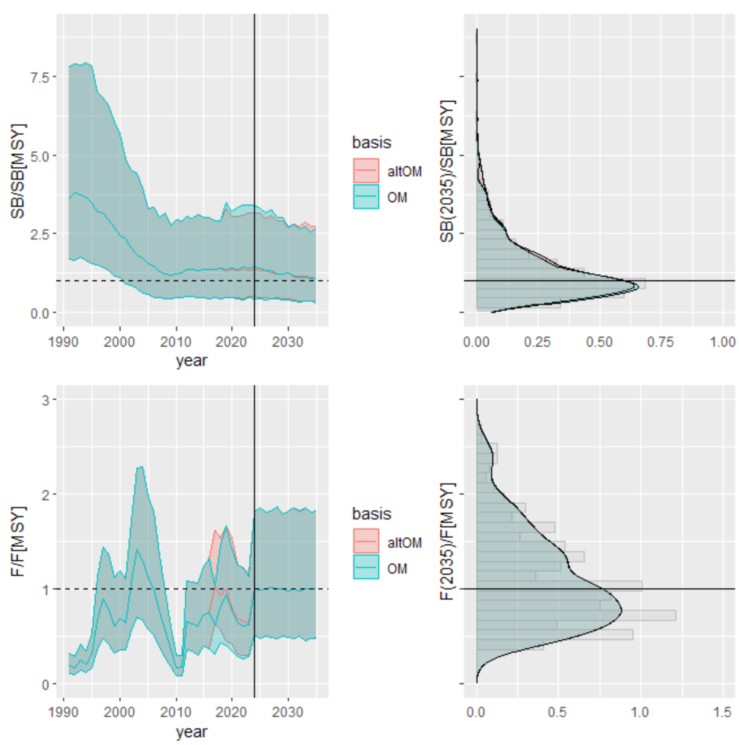

Figure 5 : projection with $F=F_{MSY}$ of the OM and an alternative OM (altOM) with recruitment deviates and fisheries selection updated according the new 2023 assessment, and comparison of stock status in 2035.

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, 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:

- with a 3 year advice cycle (TAC set for a period of 3 years)
- with an inter-annual TAC variation limit (or TAC stabilizer) for which the maximum increase in the TAC is 15% and the maximum decrease in the TAC is 10%

Model-based MP

Definition

The model-based MPs (figure 3) 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.

Implementation in the swordfish case

The surplus production model JABBA was fitted to the total catches time series and the Japanese longline CPUE index It provided estimates of the depletion rate, calculated as SB/SB0 (SB0=virgin biomass), in the last year of the assessment period. The limit and trigger depletion rates were set at CP1 = 0.1 and CP2 = 0.4. The maximum catch, CP3, was obtained by tuning the MP to achieve the particular management objectives

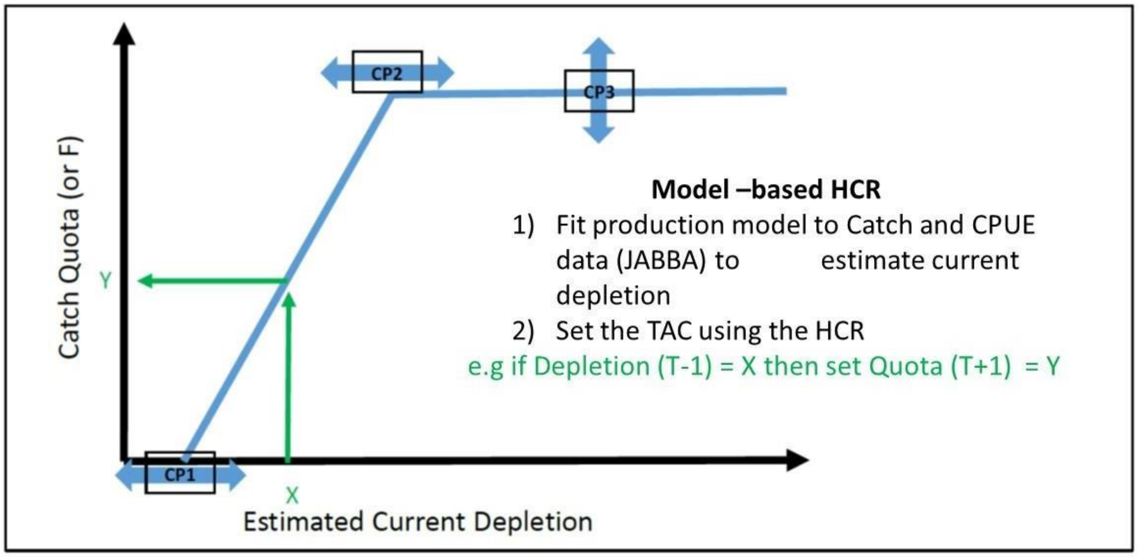

Figure 6. Harvest control rules used in the model-based MP.

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. Formally, the future TAC is calculated as a proportion, TAC_{mult}, of the current TAC, which is defined as

$$TAC_{mult} = 1 + k_a Sl + k_b D$$

with

$$k_a = k_1 if Sl > 0 \lor k_a = k_2 if Sl \leq 0$$

and

$$k_b = k_3 if D > 0 \lor k_b = k_4 if D \leq 0$$

Where Sl is the slope of the log CPUE over the last 5 years, D is the difference between recent CPUE value (average over the last 3 years) and the target CPUE value, and k_a and k_b are parameters of the relative weight assigned to the previous two quantities (figure 4), controlling the responsiveness of the MP. Control parameters include: CP1) responsiveness to CPUE slope (k1 and k2), CP3) responsiveness to CPUE target deviation (k3 and k4) and CP4) the CPUE target value.

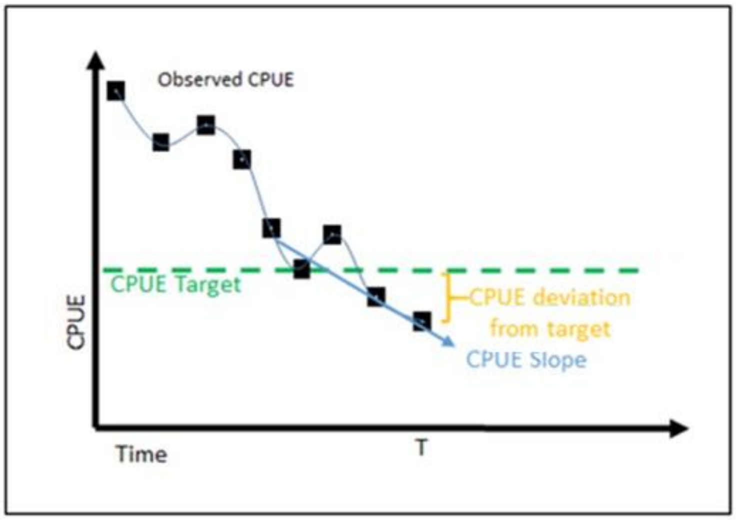

Figure 7 : The CPUE rule is based on the recent slope in the CPUE index and the distance to the target index value.

Implementation in the swordfish case

The CPUE index used for this rule was the Japanese longline CPUE index. 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.

Based on analyses presented at the last TCMP (IOTC, 2023) it was shown that management objectives could be achieved for a range of k (k1-4) value combinations, corresponding to a range of MPs reacting more or less rapidly to the year-to-year changes in the CPUE index. The choice of these k-values had an impact on different MP performance metrics other that the tuning criteria (e.g. catch variability). In order to propose two contrasting data-based MP options, two CPUE MPs implementations are proposed, having respectively low (k1 & k2 = 0.1 and K3 & k4 = 0.3) and high (k1 & k2 = 2.1 and K3 & k4 = 1.2) reactiveness parameters.

The MPs were tuned to estimate the target CPUE value for the same three management objectives as for the model based MPs.

Scenario list

Based on the requests from the 2024 TCMP (February meeting), the following list of scenarios has been defined.

Tunned MP

The MPs for which tuning should be carried out cover the 2 types of MP, model base and data base (both with fast and slow reactiveness). Tuning of these MPs should be done for 2 tuning objectives, namely 60% and 70% probability of being in the green quadrant of the Kobe plot for the period 2034-2038 (i.e. 11 to 15 years into the simulation period). The only TAC stabilizer considered is a +15%/-10% change limit. The list of the tuned MP is presented in the table 1.

Table 1 : list of proposed candidate MPs for the Indian Ocean swordfish

MP name	descriptor	MPtype	Tuning objective P(Green)=	TAC stabilizer (max up- max down)
MP1	CPUE_Fast_60%_15-10	CPUE_Fast	60%	15-10
MP2	CPUE_Fast_70%_15-10	CPUE_Fast	70%	15-10
MP3	CPUE_Slow_60%_15-10	CPUE_Slow	60%	15-10
MP4	CPUE_Slow_70%_15-10	CPUE_Slow	70%	15-10
MP5	Modelbased_60%_15-10	Model based	60%	15-10
MP6	Modelbased_70%_15-10	Model based	70%	15-10

Note : the model-based MPs (MP5 and MP6) were tuned using the OM projected until 2022. They will be tuned again using the latest version of the OM, updated until 2023.

Tests

- Implementation error

Additional runs have been requested to test the robustness of the tuned MPs to different scenarios regarding a possible overshoot of the TACs delivered by the MP. Two scenarios are considered :

  - An implementation error of 10% over a longer period of time.
  - A maximum implementation error of 15% for a single management cycle, or three years

The first test was conducted and the results are presented below. The second test will be conducted before the Mai 2024 TCMP meeting.

Summary of Swordfish Candidate MP Performance

MP rankings against key performance indicators are presented in figures 8-12 illustrate their performance characteristics. We highlight the following key points:

- All tuned MPs led to similar levels of spawning biomass (for a given tuning objective), except the model-based MP5 which leads to slightly lower biomass. The model-based MPs also led to a wider distribution of values across simulation replicates. The slow reacting data-based MPs also lead to slightly wider distributions than the fast reacting ones.
- For all tuned MPs, the probability that the stock remains above SB_{lim} for the tuning period was very high (average values above 99%).
- The data-based MPs (MP1 to MP4) led to larger average catches over the tuning period than the model-based one, but a wider distribution of values across simulation replicates. The fast reacting

data-based MP led to slightly higher catches than the slow reacting one when tuned for a 70% probability of being in the green quadrant of the Kobe plot (MP1 vs. MP3). The fast reacting data-based MPs also led to more uncertainty about future catch than the slow reacting ones. For the model-based MPs, the average catch is consistent across iterations (no variability in future values), reflecting the fact that it is most of the time equal to the plateau of the hockey stick harvest control rule.

- Catches in the short term (2024-2027) are, on the opposite, higher for the model-based MPs, also with a narrower distribution of values. The short-term catches with the fast reacting data-based MP are more uncertain that for the slow reacting one, and slightly higher when the MPs are tuned for 70% probability of being in the green quadrant of the Kobe plot.
- This also resulted in a low interannual change in the catch for the model-based MPs. For the data based MPs, the slow reacting MPs (MP3-4) have a lower interannual change in catches than the fast reacting MPs.
- Tuning objectives are achieved (mean P(Kobe=green) at 0.6 or 0.7) but there is a large variability in this probability between simulation iterations (i.e. the 25th-75th quantile interval ranges from 0 to 1). This specific point was investigated for the 2022 WPB. It was explained by the fact that most of the simulation iterations starting in a given quadrant of the Kobe plot, remain in the same quadrant throughout the simulation period, despite the implementation of a MP. This is due to several factors. First the OM has a large range of initial starting conditions, with numerous iterations far above or far below the SB_{msy}. For these iterations to change quadrant over the tuning period, it would require a MP that imposes a strong change of stock size. This is unlikely to be the case in the present situation, where the initial status for the stock is at p(Kobe=green)=73%, not far from any of the tuning objectives. In addition, due to the high longevity in the stock (31 age-classes), SB is very stable, which reduces the chances of changing quadrant over the tuning period, especially as the tuning period is rather short (5 years).

The main trade-off (figure 7) amongst MPs tested appears to be between MP type, with higher catches but larger interannual variation (and overall uncertainty) for the data-based MP, and lower but very stable catches for the model-based MP. The same trade-off is also found between the slow and fast reacting data-based MP, but with smaller differences compared to the trade-off across MP types.

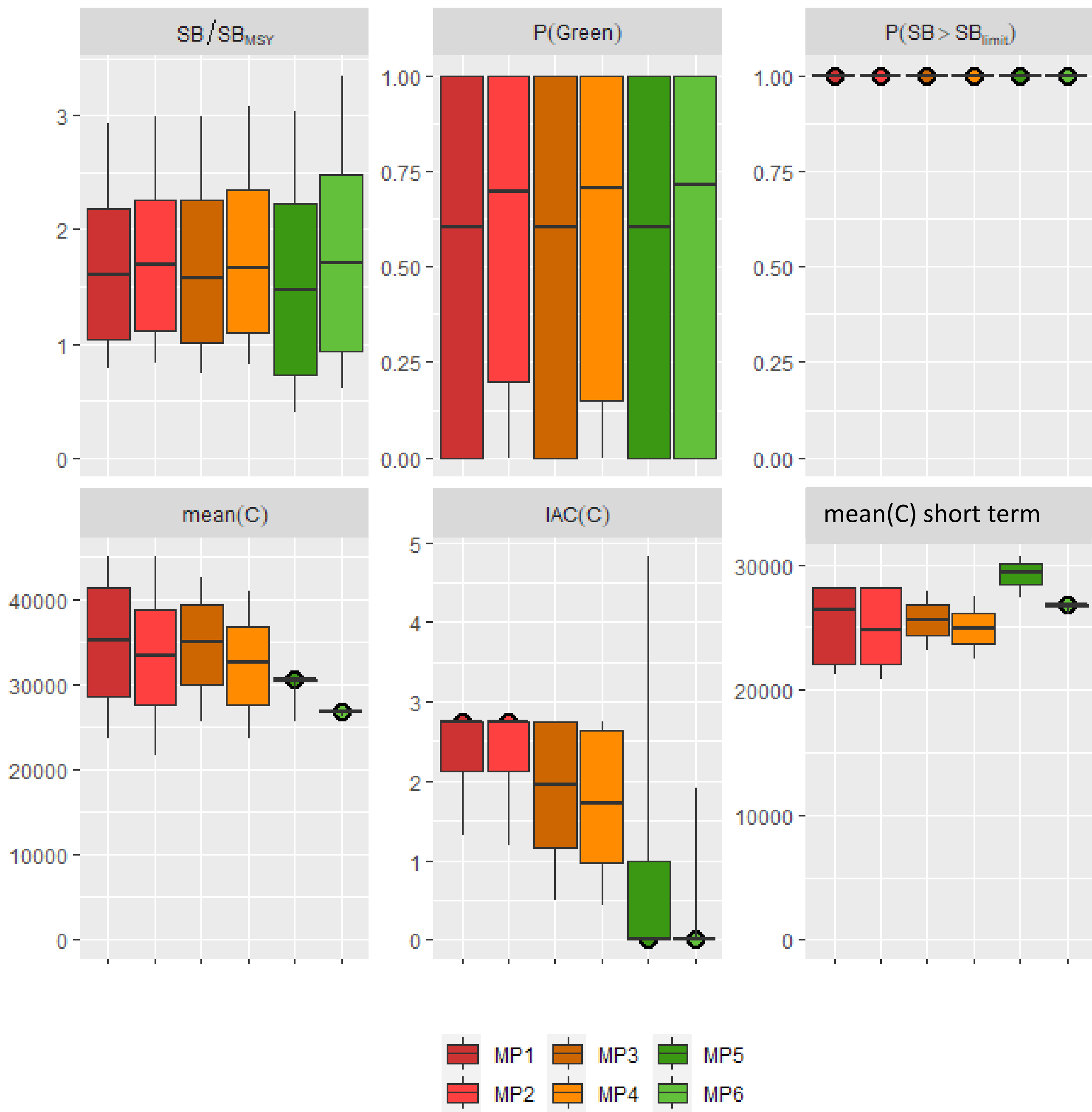

Figure 8. Boxplots comparing candidate MPs with respect to key performance measures averaged over the period 2034-2038 (except for mean(C) short term which is average for 2024-2027). Horizontal line is the median (mean for P(Green)), boxes represent 25th - 75th percentiles, thin lines represent 10th - 90th percentiles. The data-based MPs are depicted in red (fast reacting) and orange (slow reacting) and model-based MPs are depicted in green.

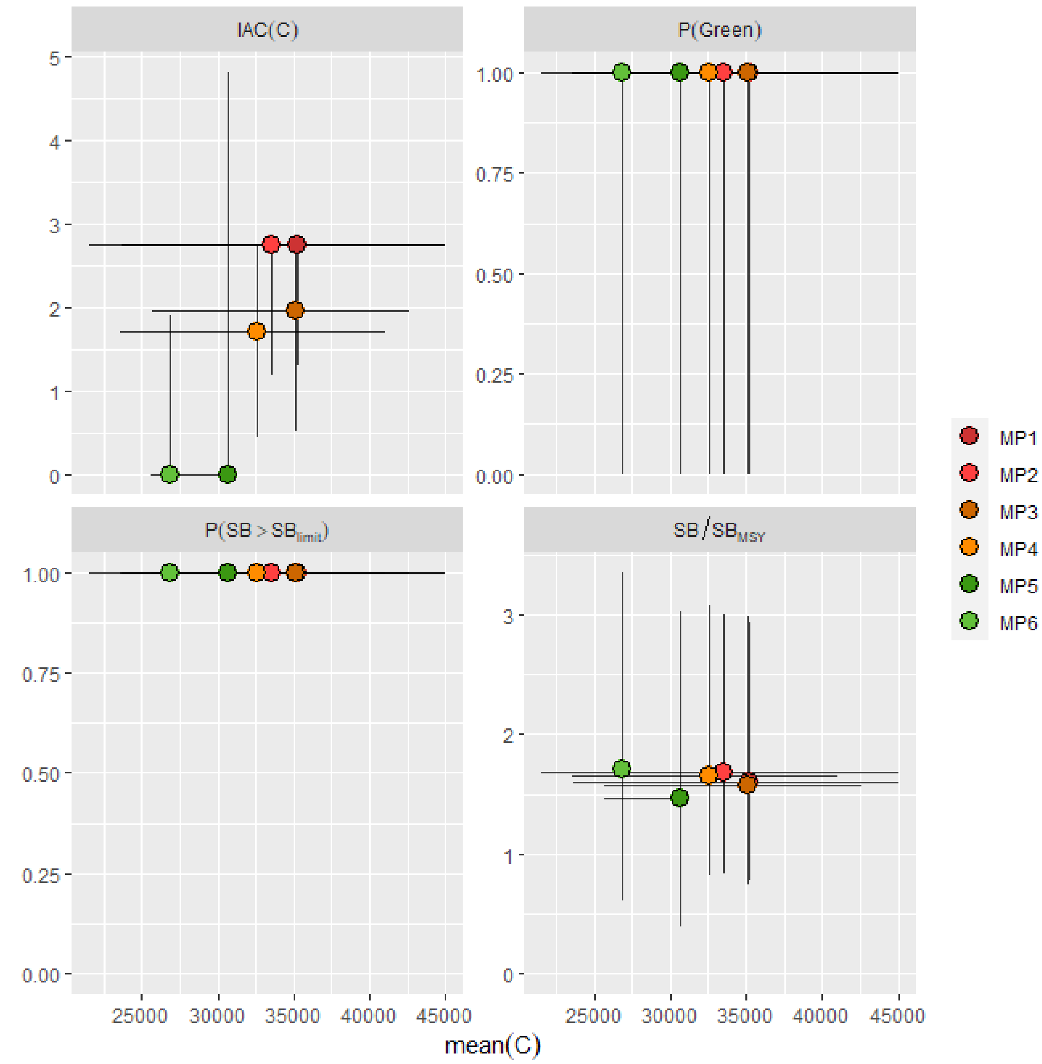

Figure 9. Trade-off plots comparing candidate MPs with respect to catch on the X-axis, and 4 other key performance measures on the Y- axis, each averaged over the period 2034-38. Circle is the median, lines represent 10th-90th percentiles.

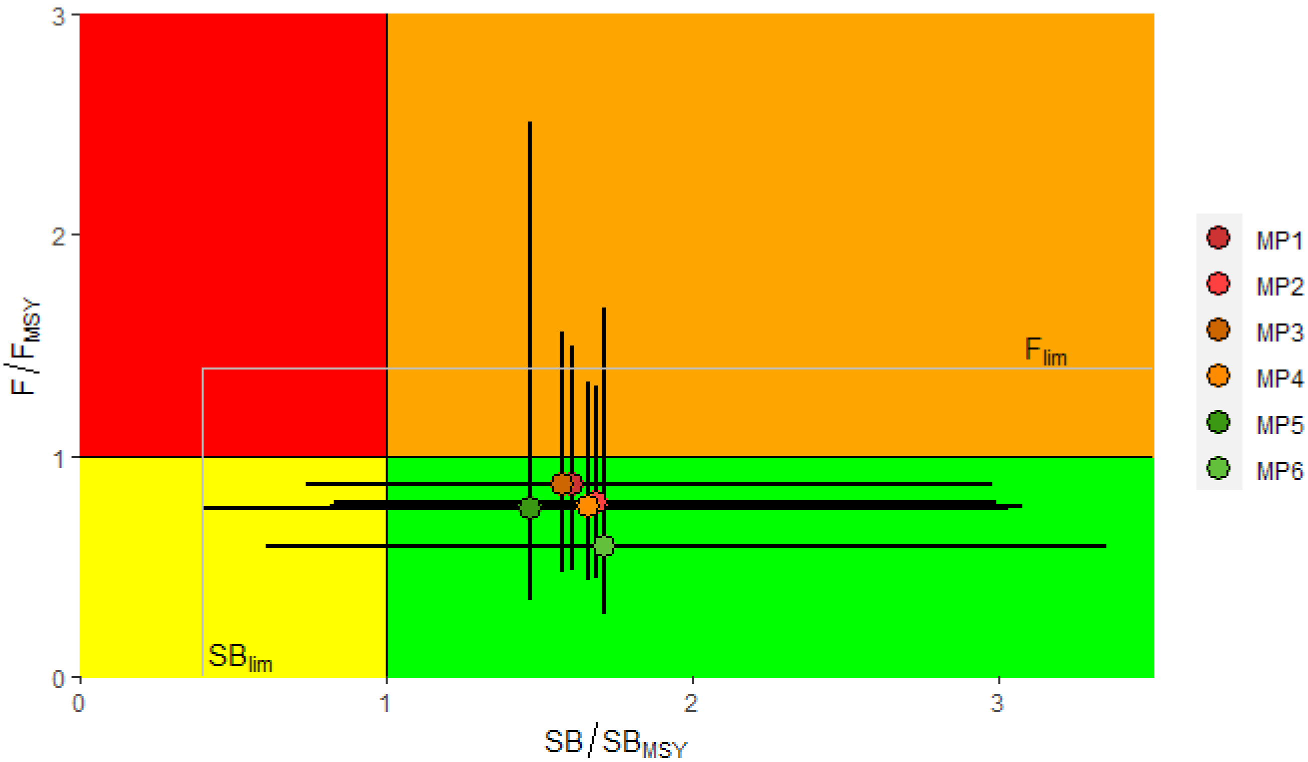

Figure 10. Kobe plot comparing candidate MPs on the basis of the expected 2034-2038 average performance. Circle is the median, lines represent 10th-90th percentiles.

Figure 11. 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.

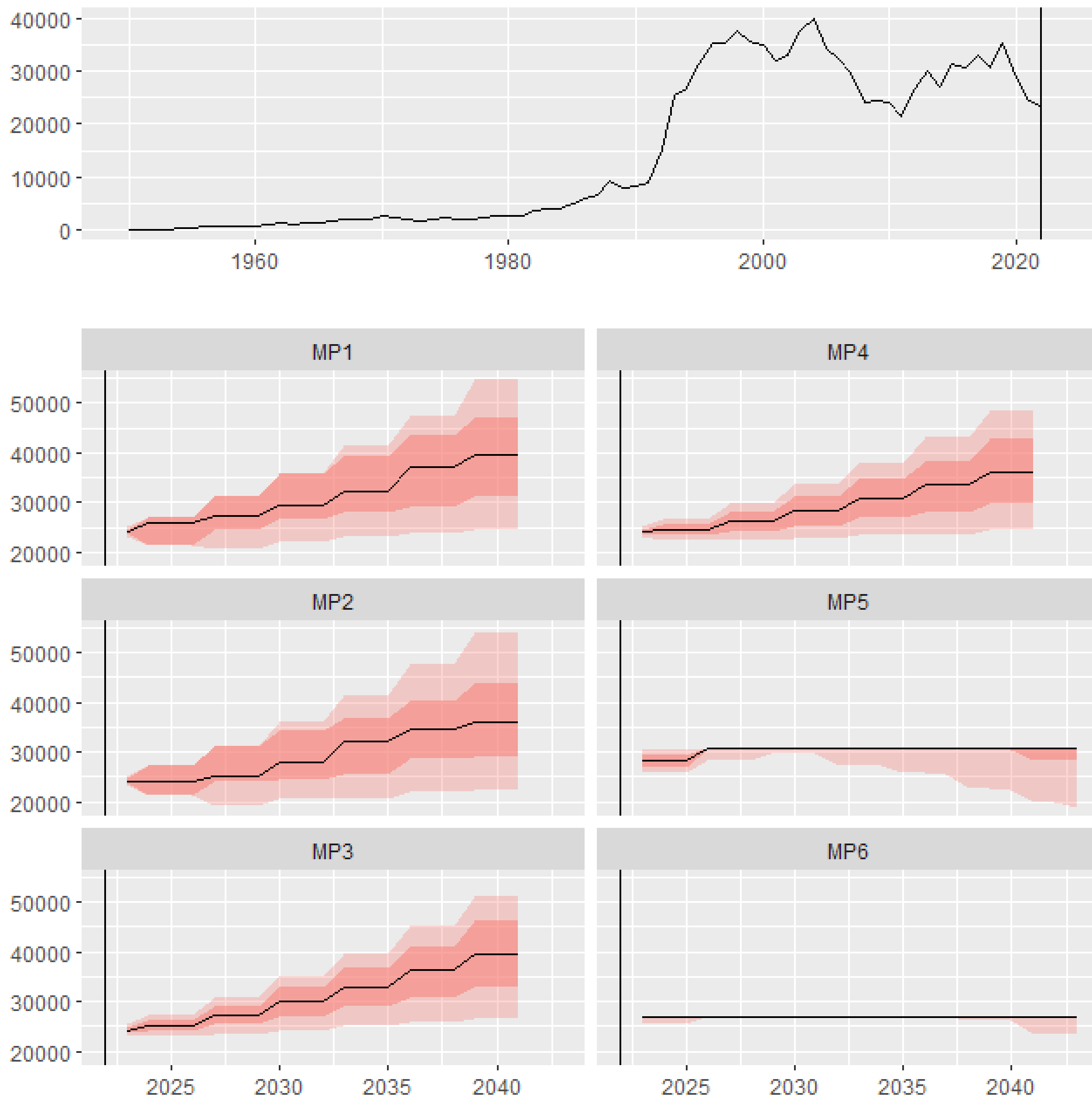

Figure 12. Time series of catch for the candidate MPs

Test runs

The runs to test the robustness of the MPs to a systematic 10% overshoot of the catch limits were carried out only for the four tuned data-based MPs (MP1 to 4). The performance of these MPs with implementation error can be compared to the performance of the MPs without implementation error by comparing figures 8 and 13.

With implementation error, the tuning criteria is no longer met, with probabilities of being in the green quadrant of the Kobe plot at 50% and 58% for the MPs tuned for 60% and 70% respectively. Similarly, the level of spawning biomass in the tuning period is lower with implementation error (1.4-1.5 compared to 1.6-1.8). As expected, due to the systematic 10% overshoot, higher catches are achieved, both in the short-term and over the tuning period. Interannual catch variability is similar. The MPs with 10% overshoot still have a very high probability that the stock remains above SB_{lim} for the tuning period.

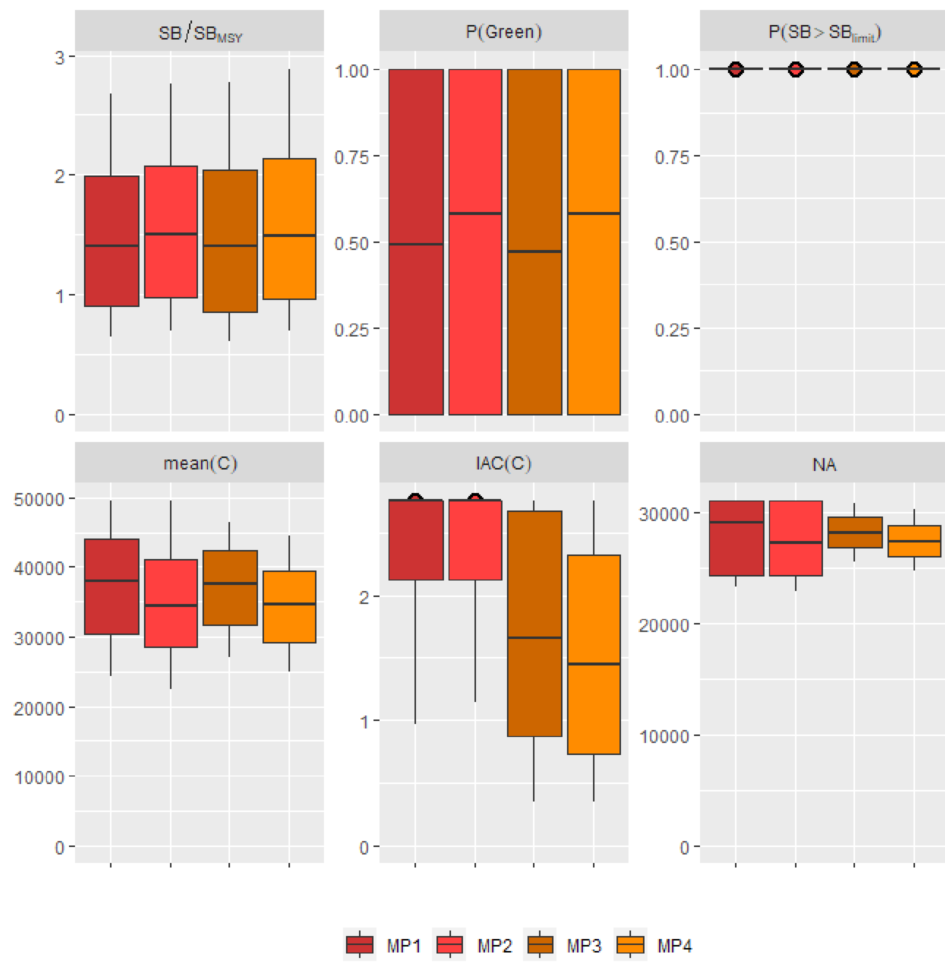

Figure 13 : Boxplots showing key performance measures (see figure 8 caption) for the tuned MP1 to 4 when run with a systematic 10% overshoot of the catch advice.

Next steps

The short term objective for this work is to conduct the missing runs to be able to present a fully updated set of results to the TCMP meeting (10-11 May 2024). This includes tuning again the model-based MPs using the latest version of the OM (updated until 2023) and conduct the missing robustness tests (test of 10% constant overshoot for the model-based MPs, and test of a 15% overshoot over the first three simulation years for all MPs.

References

IOTC, 2023. IOTC Swordfish Management Strategy Evaluation Update 6th Session IOTC TCMP – 5 & 6 May 2023IOTC-2023-TCMP06-09