Standardising the presentation of MSE results to provide clear advice for managers

Ashley J Williams[1], James Larcombe[1], Heather M Patterson[1]

Introduction

The Indian Ocean Tuna Commission (IOTC) management strategy evaluation (MSE) work program was initiated following adoption of the proposal to implement the precautionary approach for managing IOTC species in 2012 (Resolution 12/01). From this Resolution, the IOTC Scientific Committee (SC) was instructed to assess the performance of candidate management procedures (MP) through MSE, and provide the Commission with advice on their performance against Commission objectives. The IOTC Working Party on Methods (WPM) leads the technical development of MSEs for key IOTC species.

Outputs from an MSE can be extensive and complicated, and the entire MSE process is often not well-understood by non-technical audiences. Effective and consistent communication of MSE results is important to ensure that decision makers are clearly informed about the likely consequences of implementing different MPs or harvest control rules (HCR). Communication of MSE results for IOTC stocks has been relatively *ad hoc* to date, with no established guidelines for presenting MSE results to the Commission.

The use of standardised terminology and presentation formats for MSE results would facilitate a better understanding and maximise the engagement of all partners in the MP dialogue. The proposal to establish a Technical Committee on Management Procedures (TCMP) was adopted at the 20th Session of the IOTC. This committee will provide a forum in which MSE results are presented and discussed in a manner that assists the Commission to consider possible adoption of candidate MPs.

This paper outlines some of the key considerations, and presents some potential options, for developing a standardised approach for communicating MSE results to the TCMP and Commission. The intent of this paper is to provide a basis for a recommendation to the SC and TCMP for further feedback. The ultimate goal is to develop a set of guidelines for the communication of MSE results in the IOTC.

Key issues to consider in communicating MSE results

Quantity

MSEs are inherently complex and can generate a large volume of outputs. While many of these outputs are useful for presentation and discussion at the WPs and SC, most are not relevant or necessary for the Commission. The number of MSE outputs presented to the Commission needs to be minimised to avoid saturation and confusion. Too many figures and tables can be overwhelming to a non-technical audience, and could lead to disengagement in the MP dialogue.

It is important that decision makers are presented with a selection of candidate MPs (or HCRs) from which to evaluate the relative performance against the Commission objectives. However, consideration needs to be given to limit the number of MPs (or HCRs) that are presented because

[1] Australian Bureau of Agricultural and Resource Economics and Sciences, Department of Agriculture and Water Resources, Canberra ACT 2601 Australia.

there are currently 16 different performance measures used to evaluate performance. As a guide, a maximum of 6 candidate MPs (or HCRs) would seem to allow sufficient coverage of the range of potential MPs of interest whilst limiting the amount of information to communicate. Alternatively, more MPs could be presented provided that fewer performance measures are selected to convey the trade-offs among conflicting objectives.

Clarity

Outputs from MSEs can be complex and should be presented in a simple, clear and unambiguous format to ensure that results are communicated accurately and efficiently. Figures and tables should be simple to interpret, not too busy, and have clear axes, titles and legends.

It is important that MSE results clearly show the trade-offs among objectives (i.e. performance measures) across the candidate MPs or HCRs to enable the Commission to make informed decisions about the likely consequences of implementing different MPs. Therefore, the format of presentation material needs to enable a clear and direct comparison among candidate MPs.

It will also be important that decision makers can evaluate the performance of each candidate MP against all 16 performance measures. However, presenting figures for the performance of each MP against all performance measures is likely to be overwhelming. Consideration should be given to selecting a representative subset of performance measures, from each category (e.g. status, safety, yield, abundance and stability), for presentation in figures.

Consistency

An examination of the MSE literature highlights the numerous formats in which MSE results can be presented. Even within the IOTC, different formats have been used to present MSE outputs. The use of a variety of different presentation formats can result in confusion and, more concerning, misinterpretation of results by a non-technical audience, which ultimately does not serve the Commission well. Achieving consistency in the presentation of MSE outputs, including the terminology used, is clearly a desirable goal for the IOTC as it would build familiarity with the MSE process and minimise the likelihood of misinterpretation. Therefore, a standardised format for presenting MSE outputs to the TCMP and the Commission should be developed across all key IOTC species. The compilation and adoption of a glossary of MSE terminology would assist in achieving greater consistency in presenting MSE results.

Relevancy

Given that not all MSE outputs can be presented to decision makers, it is important that the outputs presented are the most relevant to the decision making process. The MSE outputs presented should include all information that is essential to make decisions, while excluding unnecessary information that would not inform decisions and that may be confusing.

The Commission is likely to have specific preferences for the presentation of some MSE outputs. For example, participants at the 3rd Management Procedures Dialogue (MPD) requested that candidate MPs are compared with *status quo* management (i.e. no change in current management arrangements). This will require clear specification from the TCMP and Commission on what 'current management' means (e.g. constant effort, constant catch etc.). Participants at the MPD also remarked on the usefulness of the ability of the scientists to respond rapidly to requests for additional information made during the MPD and encouraged such an interactive presentation of results at future TCMP meetings.

Uncertainty

Uncertainty in MSE outputs should be described transparently. Clear communication about the uncertainties in the MSE process will allow decision makers to make better choices from among

candidate MPs. Therefore, presentation of MSE results should clearly depict the uncertainties in the MSE results (e.g. error bars on figures). If possible, results should be presented in the form of risk statements, which inherently capture uncertainty. For example, there is an XX% risk that this candidate MP will cause the spawning biomass to fall below the limit reference point over the next YY years.

Adaptability

As the MSE work program develops in the IOTC, there will be a need to periodically review any guidelines for presenting MSE results. While this will inevitably involve revisions to the format of presentation material, efforts should be made to minimise changes to preserve the general format and appearance of presentation material and maintain familiarity for decision makers. Revision of guidelines would be the responsibility of the SC and its working parties, based on outcomes from TCMP meetings.

Repeatability

To ensure consistency and clarity, it is important that the presentation material can be reproduced accurately and efficiently for each MSE presentation. To facilitate this, source code for generating the presentation material should be freely available and shared among scientists, as is currently practiced by the WPM (e.g. https://github.com/iotcwpm), noting that presentation formats may evolve through continuous dialogue between the WPM, SC, TCMP and Commission.

Proposal for presenting MSE results

Establishing detailed guidelines for the precise presentation of MSE outputs will be difficult at this stage. However, there is an opportunity to develop some general guidelines for the layout of the material to present to the TCMP and Commission. Here, we outline a proposal for presenting outputs from a hypothetical MSE. For illustration, we use 6 hypothetical MPs, and indicate their performance against the 16 performance measures. For simplicity, we illustrate only the harvest control rule (HCR) component of the MP, and exclude other components such as the data collection and assessment method.

The elements of the proposed presentation material are as follows:

1. Illustrate the MPs that have been evaluated in a figure and briefly define them in a table.
2. Present the results for the performance of each MP:
    a. Against a representative subset of performance measures in a comparative figure
    b. Against the B/B_{MSY} and F/F_{MSY} performance measures in a Kobe plot.
    c. Against the stock size and fishing intensity performance measures in time series plots.
3. Provide a clear and succinct summary of the performance of each MP.
4. Provide the numerical results for each MP across all 16 performance measures endorsed by the SC in a table in an appendix.

1. Define Management Procedures

It will be important that decision makers have a clear understanding of the MPs (or HCRs) that have been evaluated. To achieve this, a clear description of each MP (or HCR) should be presented prior to the MSE results, along with an explanation of the relevant decision steps involved i.e. what to do, and when to do it. The 6 hypothetical example MPs are illustrated in Figure 1, and a brief description of each is provided in Table 1. Note that the example MPs and reference points are based on current biomass relative to unfished biomass, where current biomass is that estimated in the last year of data (2015) and unfished biomass is that estimated in 1950. The same general illustration of MPs would apply if using MPs and reference points based on maximum sustainable yield (MSY).

2. Performance of Management Procedures

a. Subset of performance measures

The key plots for communicating MSE results should clearly indicate the relative performance of each MP (or HCR) that was evaluated against a representative subset of performance measures from each category (e.g. status, safety, yield, abundance and stability). These plots should clearly indicate the uncertainties in the MSE using error bars to represent percentiles. The performance of the 6 MPs in the hypothetical example MSE is illustrated for 6 performance measures in Figure 2. While this example depicts results averaged over the last 20 years of the projection period, other summary periods or multiple summary periods may be more appropriate.

A summary table that ranks the performance of each MP against the key performance measures is shown in Table 2. Note that the rankings in Table 2 simply indicate the relative ranking of each MP, and do not indicate whether individual MPs perform well or not. The overall ranking is unweighted, so each performance measure has equal weight.

b. Kobe plot

At the 3rd MPD, participants requested that the Kobe plot (SB/SB_{MSY} versus F/F_{MSY}) be used to present the performance of evaluated MPs, and that further refinement of this figure should be undertaken in future. The performance of the 6 MPs in the hypothetical example MSE is illustrated in a Kobe plot in Figure 3. Consistent with the adopted guidelines for presenting stock assessment results, the Kobe plot indicates target and limit reference points.

c. Time series plots

Figures 2 and 3 use an average or median of each performance measure over a particular period of time (20 years, final projection year, respectively), but there is no information on the trajectory of the performance measure over time. Decision makers may be interested to see a predicted trajectory for key performance measures, as it can reveal if a performance measure for an MP drifts into an undesirable state during the projection period. Time series plots for the hypothetical example of the performance of 6 MPs are illustrated in Figure 4 for the stock size performance measure and in Figure 5 for the fishing intensity performance measure. Time series plots for additional performance measures may also be relevant. The key elements depicted in these figures are the median of all runs and the 75th and 90th percentiles and the target and limit reference points. A sample of individual realizations could be added to these plots to illustrate the typically erratic nature of individual trajectories, but were not added here to improve clarity.

3. Summary performance of Management Procedures and management advice

To assist with decisions on adopting candidate MPs, the Commission will require some guidance on the performance of each candidate MP, in addition to the figures and tables provided. A clear and succinct summary statement comparing the relative performance of each MP against the performance measures would allow the Commission to evaluate the trade-offs among alternative MPs when making such decisions.

The following statement provides an example summary of the performance for each of the 6 hypothetical MPs.

- MP1 performed very well for maintaining high catches, and performed average for maintaining high catch rates and low catch variability. However, MP1 performed very poorly at maintaining biomass and fishing mortality away from limit reference points and close to target reference points. There is a 20% risk that MP1 will cause the spawning biomass to fall below the limit reference point and a 50% risk that MP1 will cause the fishing mortality to exceed the limit reference point over the next 20 years.

- MP2 performed very well for maintaining biomass and fishing mortality away from limit reference points and close to target reference points, and performed very well at maintaining high catch rates. MP2 performed very poorly for maintaining high catches and low catch variability. There is a 0% risk that MP2 will cause the spawning biomass to fall below the limit reference point and or the fishing mortality to exceed the limit reference point over the next 20 years.
- MP3 consistently outperformed all other MPs for maintaining biomass and fishing mortality away from limit reference points and close to target reference points, and achieved the highest catch rates. However, MP3 performed the poorest for maintaining high catches and low catch variability. There is a 0% risk that MP3 will cause the spawning biomass to fall below the limit reference point or the fishing mortality to exceed the limit reference point over the next 20 years.
- MP4 performed average for maintaining biomass and fishing mortality away from limit reference points and close to target reference points, and average for maintaining low variability in catch. However, MP4 performed poorly at maintaining high catches and catch rates. There is a 0% risk that MP4 will cause the spawning biomass to fall below the limit reference point or the fishing mortality to exceed the limit reference point over the next 20 years.
- MP5 outperformed all other MPs for maintaining high catches and low catch variability. However, MP5 performed the poorest for maintaining high catch rates and maintaining biomass and fishing mortality away from limit reference points and close to target reference points. MP5 breached the limit reference points in 10 years out of 20 years. There is a 5% risk that MP5 will cause the spawning biomass to fall below the limit reference point and a 50% risk that MP5 will cause the fishing mortality to exceed the limit reference point over the next 20 years.
- MP6 performed average for maintaining high catches and performed well for maintaining low catch variability. However, MP6 performed poorly for maintaining high catch rates. MP6 performed average for maintaining biomass and fishing mortality away from limit reference points and close to target reference points. There is a 60% risk that MP6 will cause the spawning biomass to fall below the limit reference point or the fishing mortality to exceed the limit reference point over the next 20 years.

4. Full set of results for each Management Procedure

While the main presentation of MSE results should focus on a selection of key performance measures summarised for a single time period, it is possible that the Commission will have interest in seeing the results for other performance measures or the same performance measures for a different summary time period. Therefore, the numerical results for each MP across all 16 performance measures and for the different time periods evaluated should be provided for reference in a table in an appendix. Table 3 provides an example table for the hypothetical MSE outputs comparing the performance of 6 MPs against all IOTC performance measures for 4 time periods (1, 5, 10, and 20 years). Additional information, such as percentiles ranges, could be added in parentheses for each value.

Recommendation

This paper aims to facilitate discussion on how to improve communication of MSE results to the TCMP and Commission. Based on the outcomes from this discussion, this paper seeks a recommendation from the Working Party on Methods that a revised proposal for standardising the presentation of MSE results be submitted to the SC and TCMP for input, leading ultimately to the adoption of guidelines for the presentation material used by the WPM and SC in communicating MSE results to the TCMP and Commission.

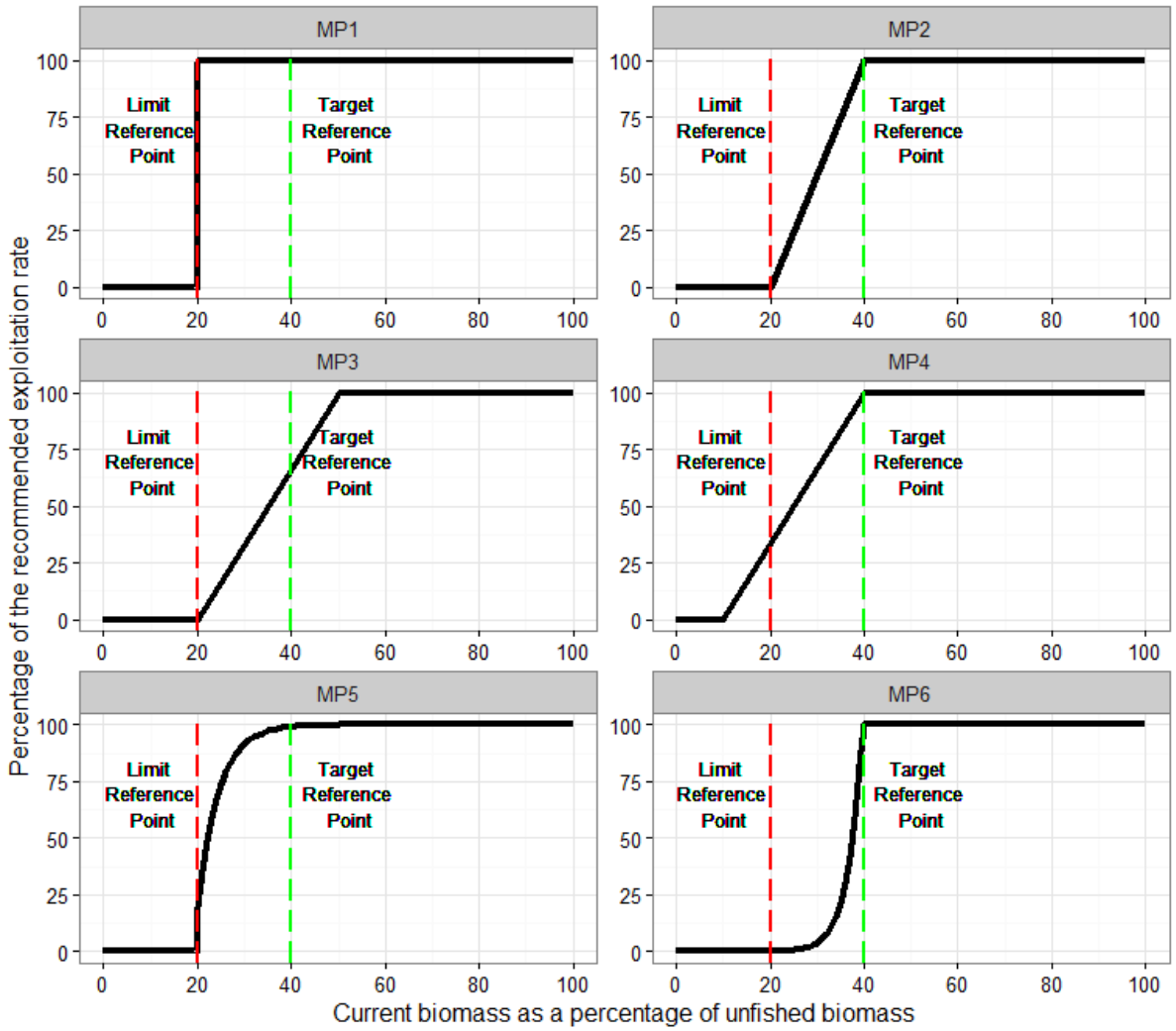

Figure 1. Illustration of six hypothetical example management procedures (MPs) relating the percentage of the recommended exploitation rate to stock status (current biomass relative to unfished biomass). A limit reference point of 20% of unfished spawning biomass and target reference point of 40% of unfished biomass are indicated by red and green dashed lines respectively.

Table 1. Brief description of six hypothetical example management procedures (MPs) illustrated in Figure 1

Management Procedure	Brief description
MP1	Full recommended exploitation rate when current biomass is equal to or greater than 20% of unfished biomass; No exploitation when current biomass less than 20% of unfished biomass.
MP2	Full recommended exploitation rate when current biomass is equal to or greater than 40% of unfished biomass; No exploitation when current biomass less than 20% of unfished biomass; Recommended exploitation rate declines linearly between 40% and 20% of unfished biomass.
MP3	Full recommended exploitation rate when current biomass is equal to or greater than 50% of unfished biomass; No exploitation when current biomass less than 20% of unfished biomass; Recommended exploitation rate declines linearly between 50% and 20% of unfished biomass.
MP4	Full recommended exploitation rate when current biomass is equal to or greater than 40% of unfished biomass; No exploitation when current biomass less than 10% of unfished biomass; Recommended exploitation rate declines linearly between 40% and 10% of unfished biomass.
MP5	Full recommended exploitation rate when current biomass is equal to or greater than 40% of unfished biomass; No exploitation when current biomass less than 20% of unfished biomass; Recommended exploitation rate increases exponentially between 20% and 40% of unfished biomass.
MP6	Full recommended exploitation rate when current biomass is equal to or greater than 40% of unfished biomass; No exploitation when current biomass less than 20% of unfished biomass; Recommended exploitation rate declines exponentially between 40% and 20% of unfished biomass.

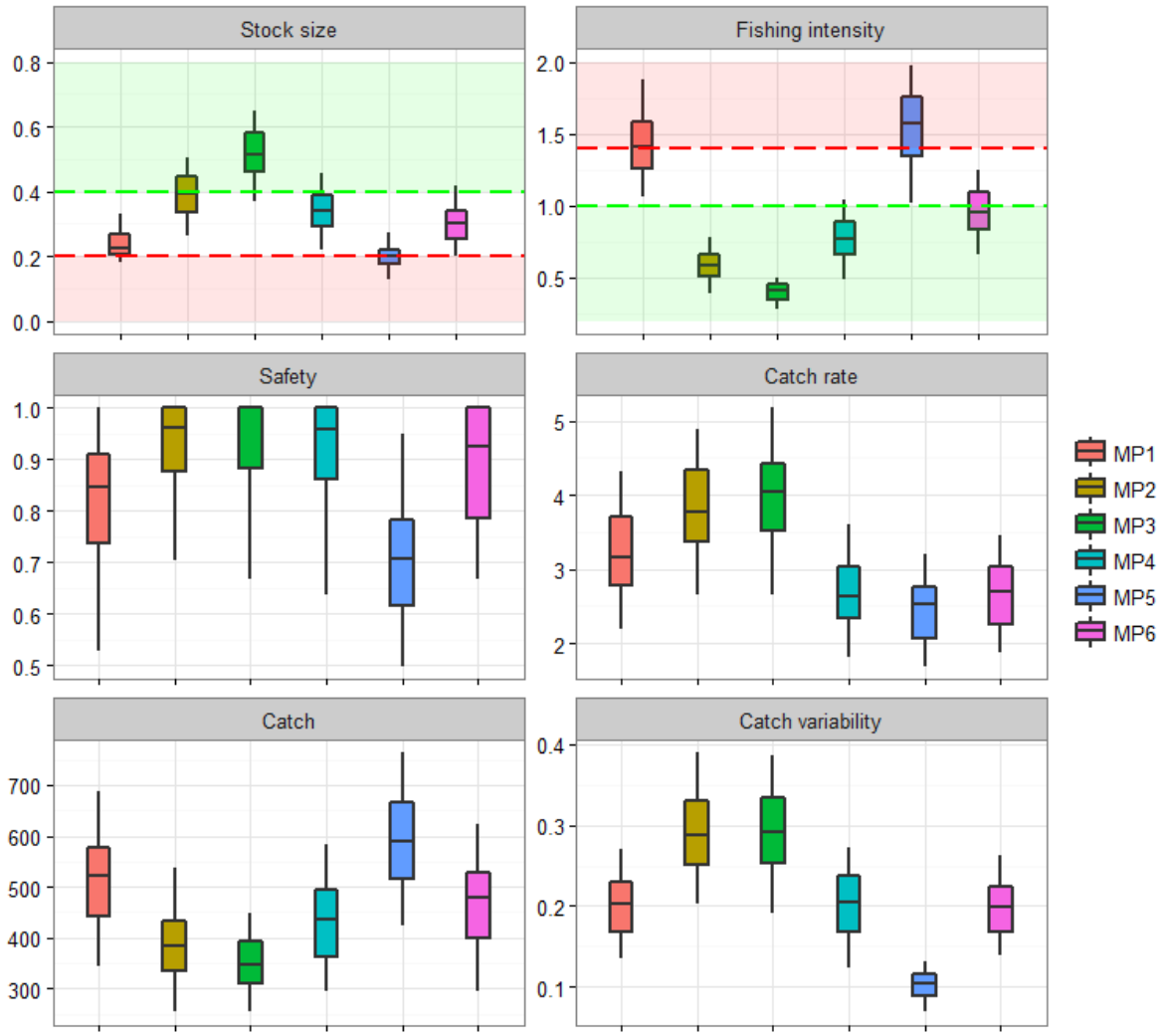

Figure 2. Hypothetical example of MSE outputs comparing the performance of 6 management procedures (MPs) against 6 performance measures. Each data point represent the median over the last 20 years of the projection period as the horizontal line, 25th -75th percentiles as coloured bars, and 5th -95th percentiles as thin lines. Limit and target reference points for the biomass and fishing mortality performance measures are indicated by red and green dashed lines respectively.

Table 2. Relative ranking of the performance (1 = high, 6 = low) of six hypothetical example MPs against six key performance measures averaged over the last 20 years of the projection period. See Figure 2 for more detail on performance of each MP.

Management Procedure	Performance Measure						
	Stock size	Fishing intensity	Safety	Catch rate	Catch	Catch variability	**Overall rank**
MP1	5	5	5	3	2	4	5
MP2	2	2	2	2	5	5	2
MP3	1	1	1	1	6	6	1
MP4	3	3	3	5	4	3	3
MP5	6	6	6	6	1	1	6
MP6	4	4	4	4	3	2	3

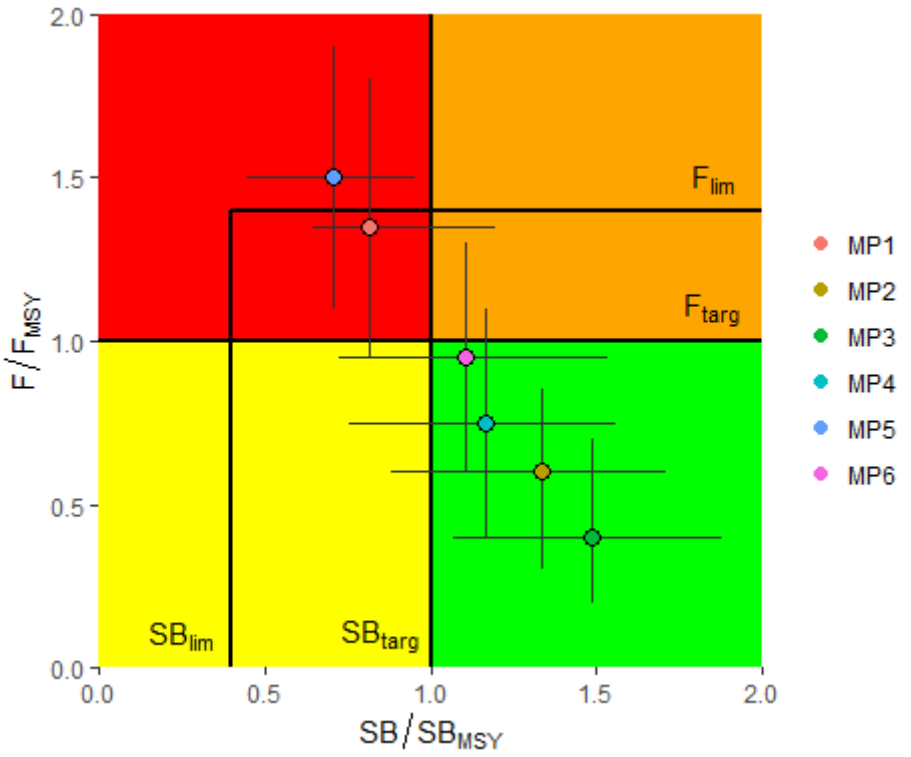

Figure 3. Kobe plot for hypothetical example of MSE outputs comparing 6 management procedures (MPs) against performance measures for SB/SB_{MSY} and F/F_{MSY}. Each data point represent the median in the final year of the projection period and the error bars represent the 95th percentiles. Target (SB_{targ} and F_{targ}) and limit (SB_{lim} and F_{lim}) reference points are indicated by black lines.

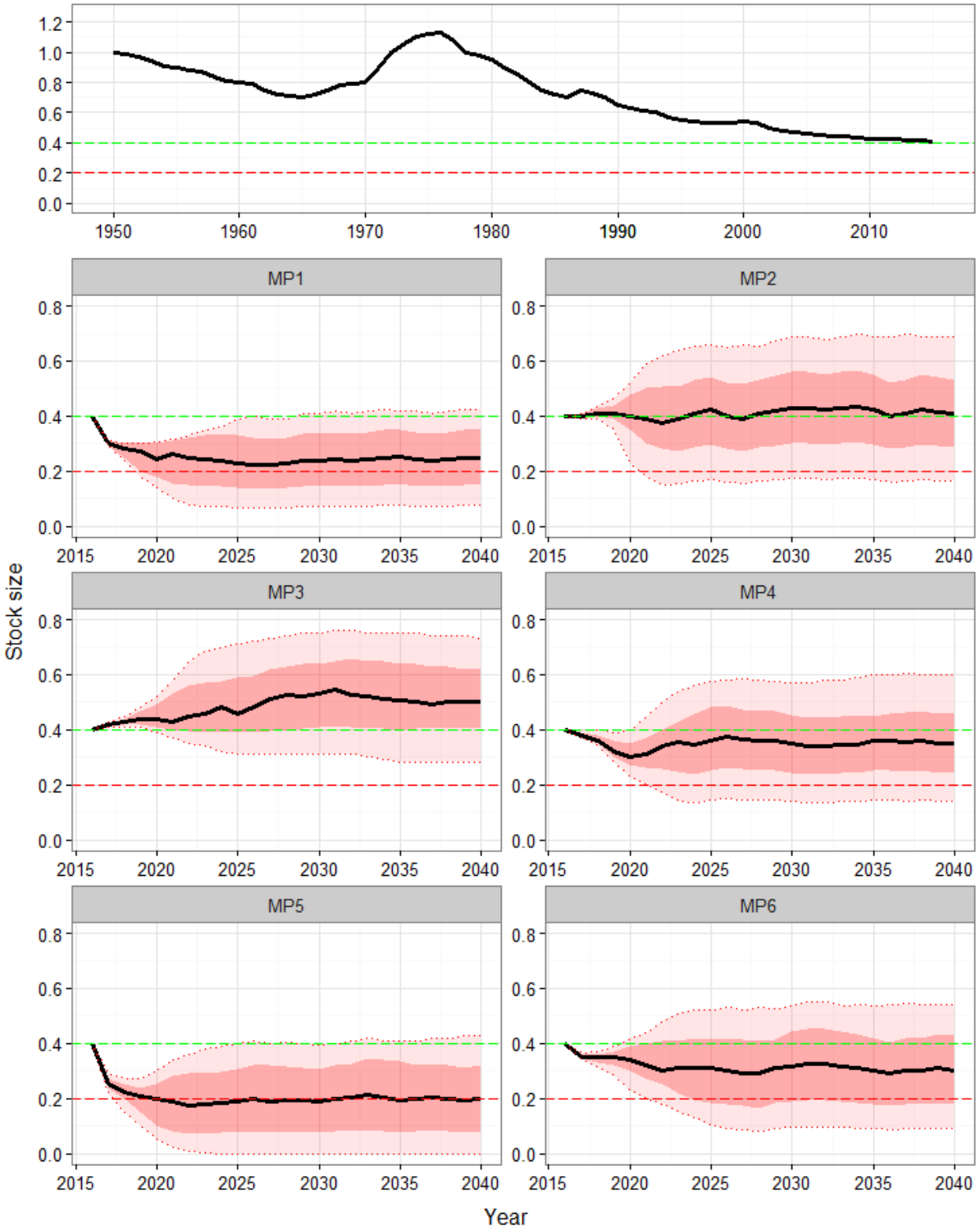

Figure 4. Time series plots for a hypothetical example of the performance of 6 MPs against the stock size performance measure. The top panel represents the historical period (1950-2015) and the bottom 6 panels represent the projection years (2016-2040). The median for each MP is represented by the bold black lines, a dark ribbon shades the 25th-75th percentile region and a light ribbon shades the 10th-90th percentile region. Horizontal lines indicate target (green) and limit (red) reference points.

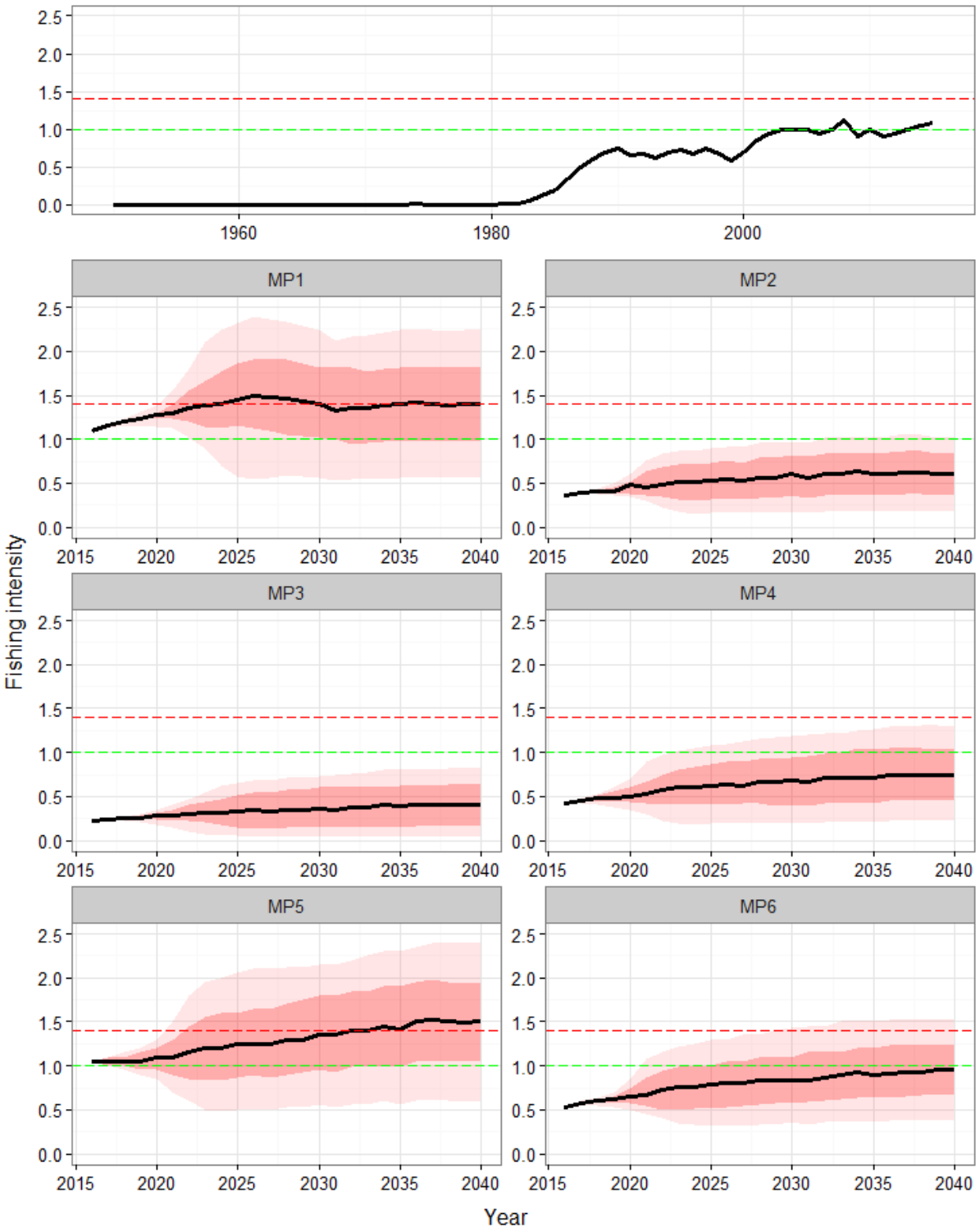

Figure 5. Time series plots for a hypothetical example of the performance of 6 MPs against the fishing intensity performance measure. The top panel represents the historical period (1950-2015) and the bottom 6 panels represent the projection years (2016-2040). The median for each MP is represented by the bold black lines, a dark ribbon shades the 25th-75th percentile region and a light ribbon shades the 10th-90th percentile region. Horizontal lines indicate target (green) and limit (red) reference points.

Table 3. Hypothetical example of MSE outputs comparing the performance of 6 management procedures (MPs) against all IOTC performance measures for 2 time periods (1 years and 5 years).

Status : maximize stock status		1 year						5 years					
		MP1	MP2	MP3	MP4	MP5	MP6	MP1	MP2	MP3	MP4	MP5	MP6
1. Mean spawner biomass relative to pristine	SB/SB_0	0.5	0.8	0.9	0.7	0.4	0.6	0.5	0.8	1.0	0.7	0.4	0.6
2. Minimum spawner biomass relative to pristine	SB/SB_0	0.3	0.6	0.6	0.5	0.2	0.4	0.3	0.5	0.6	0.5	0.2	0.4
3. Mean spawner biomass relative to SB_{MSY}	SB/SB_{MSY}	0.8	1.3	1.4	1.2	0.7	1.1	0.9	1.2	1.3	1.1	0.7	1.2
4. Mean fishing mortality relative to target	F/F_{tar}	1.4	0.6	0.4	0.8	1.5	0.9	1.4	0.6	0.4	0.8	1.5	0.9
5. Mean fishing mortality relative to *Fmsy*	F/F_{MSY}	1.4	0.6	0.4	0.8	1.5	0.9	1.5	0.5	0.4	0.8	1.6	0.9
6. Probability of being in Kobe green quadrant	*SB,F*	0.5	0.9	1	0.8	0.3	0.7	0.5	0.9	0.9	0.8	0.3	0.7
7. Probability of being in Kobe red quadrant	*SB,F*	0.3	0.1	0	0.1	0.5	0.2	0.3	0.1	0.0	0.1	0.5	0.2
Safety : m*aximize the probability of remaining above low stock status (i.e. minimize risk)*													
8. Probability of spawner biomass being above 20% of *SB0*	*SB*	0.8	0.9	0.9	0.8	0.7	0.8	0.8	0.8	0.9	0.8	0.7	0.8
9. Probability of spawner biomass being above B_{Lim}	*SB*	0.8	1.0	1.0	0.9	0.7	0.9	0.8	1.0	1.0	0.9	0.7	0.8
Yield : maximize catches across regions and gears													
10. Mean catch (1'000 t)	*C*	520	390	350	430	600	460	551	417	378	434	600	460
11. Mean catch by region and/or gear (1'000 t)	*C*	250	200	180	210	310	220	248	194	176	229	335	218
12. Mean catch relative to MSY	*C/MSY*	1.1	0.7	0.6	0.8	1.2	0.9	1.2	0.6	0.6	0.8	1.3	1.0
Abundance: maximize catch rates to enhance fishery profitability													
13. Mean catch rates (by region and gear) (for fisheries with meaningful catch-effort relationship)	*I*	3.2	3.8	3.9	2.7	2.5	2.6	3.0	3.8	4.0	2.6	2.3	2.8
Stability: maximize stability in catches to reduce commercial uncertainty													
14. Mean absolute proportional change in catch	*C*	0.2	0.3	0.3	0.2	0.1	0.2	0.2	0.3	0.3	0.2	0.1	0.2
15. % Catch co-efficient of variation	*C*	20	25	24	18	12	21	19.4	27.3	26.2	17.6	11.5	21.0
16. Probability of shutdown	*C*	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table 3. cont. Hypothetical example of MSE outputs comparing the performance of 6 management procedures (MPs) against all IOTC performance measures for 2 time periods (10 years and 20 years).

Status : maximize stock status		10 years						20 years					
		MP1	MP2	MP3	MP4	MP5	MP6	MP1	MP2	MP3	MP4	MP5	MP6
1. Mean spawner biomass relative to pristine	SB/SB_0	0.5	0.8	0.9	0.7	0.4	0.6	0.5	0.8	1.0	0.7	0.4	0.6
2. Minimum spawner biomass relative to pristine	SB/SB_0	0.3	0.6	0.6	0.5	0.2	0.4	0.3	0.5	0.6	0.5	0.2	0.4
3. Mean spawner biomass relative to SB_{MSY}	SB/SB_{MSY}	0.8	1.3	1.4	1.2	0.7	1.1	0.9	1.2	1.3	1.1	0.7	1.2
4. Mean fishing mortality relative to target	F/F_{tar}	1.4	0.6	0.4	0.8	1.5	0.9	1.4	0.6	0.4	0.8	1.5	0.9
5. Mean fishing mortality relative to *Fmsy*	F/F_{MSY}	1.4	0.6	0.4	0.8	1.5	0.9	1.5	0.5	0.4	0.8	1.6	0.9
6. Probability of being in Kobe green quadrant	*SB,F*	0.5	0.9	1	0.8	0.3	0.7	0.5	0.9	0.9	0.8	0.3	0.7
7. Probability of being in Kobe red quadrant	*SB,F*	0.3	0.1	0	0.1	0.5	0.2	0.3	0.1	0.0	0.1	0.5	0.2
Safety : m*aximize the probability of remaining above low stock status (i.e. minimize risk)*													
8. Probability of spawner biomass being above 20% of *SB0*	*SB*	0.8	0.9	0.9	0.8	0.7	0.8	0.8	0.8	0.9	0.8	0.7	0.8
9. Probability of spawner biomass being above B_{Lim}	*SB*	0.8	1.0	1.0	0.9	0.7	0.9	0.8	1.0	1.0	0.9	0.7	0.8
Yield : maximize catches across regions and gears													
10. Mean catch (1'000 t)	*C*	520	390	350	430	600	460	551	417	378	434	600	460
11. Mean catch by region and/or gear (1'000 t)	*C*	250	200	180	210	310	220	248	194	176	229	335	218
12. Mean catch relative to MSY	*C/MSY*	1.1	0.7	0.6	0.8	1.2	0.9	1.2	0.6	0.6	0.8	1.3	1.0
Abundance: maximize catch rates to enhance fishery profitability													
13. Mean catch rates (by region and gear) (for fisheries with meaningful catch-effort relationship)	*I*	3.2	3.8	3.9	2.7	2.5	2.6	3.0	3.8	4.0	2.6	2.3	2.8
Stability: maximize stability in catches to reduce commercial uncertainty													
14. Mean absolute proportional change in catch	*C*	0.2	0.3	0.3	0.2	0.1	0.2	0.2	0.3	0.3	0.2	0.1	0.2
15. % Catch co-efficient of variation	*C*	20	25	24	18	12	21	19.4	27.3	26.2	17.6	11.5	21.0
16. Probability of shutdown	*C*	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01