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Mixed-fishery harvest strategy performance indicators

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Executive Summary

WCPFC12 agreed to a workplan for the adoption of harvest strategies for WCPO skipjack, bigeye, yellowfin and South Pacific albacore tuna. An important consideration when developing harvest strategies for these stocks is to account for mixed- fishery interactions. SC15 agreed to consider developing a multi-species modelling framework, based on single stock management procedures (MPs).

The development and calculation of mixed-fishery performance indicators is an important component of the WCPO harvest strategy development. They will provide information to support the selection of preferred single stock MPs with particular attention paid to the mixed-fishery interactions. For example, it is important to understand how the bigeye stock could potentially be affected by the selection of the skipjack MP.

This report presents the results of some preliminary indicators for skipjack, bigeye and yellowfin. The evaluations were performed using the framework presented in WCPFC-SC17-2021/MI-WP-05 using a range of skipjack MPs. In the evaluations presented here there is no dynamic bigeye MP, i.e. one that sets fishing opportunities for the TLL fisheries based on the stock status of bigeye. Instead, three bigeye 'MPs' based on scenarios for constant future levels of bigeye catch by the TLL fisheries are evaluated. Evaluations are performed for each combination of the skipjack and bigeye MPs.

Four performance indicators are calculated for each stock: probability of SB/SBF=0 falling below the Limit Reference Point; expected SB/SBF=0; expected catches; and the 'impact' of each MP on each stock.

A key consideration is how to present these indicators. In particular, the catch and impact indicators can be calculated over many different dimensions, e.g. different model regions and fisheries, making them potentially challenging to interpret.

Noting that the role of the indicators is to support the selection of the preferred MPs, careful consideration must be given as to how useful these indicators are. If an indicator is unclear, or presents information that is difficult to interpret, then it should not be considered further.

The next steps include:

- Refining and continuing to develop the mixed-fishery indicators;
- Considering candidate bigeye MPs within the multi-species modelling framework; and
- Including South Pacific albacore in the evaluations.

We invite WCPFC-SC to:

- Provide feedback on the indicators presented here, particularly on how useful they are and whether any, such as the impact indicator, should not be considered further; and
- Suggest additional indicators that could be included.

1 Introduction

WCPFC12 agreed to a workplan for the adoption of harvest strategies for WCPO skipjack (SKJ), bigeye (BET), yellowfin (YFT) and South Pacific albacore (SPA) tuna. An important consideration when developing harvest strategies for these stocks is to account for mixed- fishery interactions (Scott et al., 2019). SC15 agreed to initially consider the multi-species modelling framework for developing mixed-fishery harvest strategies (WCPFC, 2019). Under this framework, fisheries are managed through single stock MPs for SKJ, BET and SPA. A detailed overview of the multi-species modelling framework is given in Scott et al. (2022a).

The three single stock MPs control the fishing opportunities for different WCPO fisheries by setting catch or effort limits based on status estimates of the associated stock. Purse seine, pole and line, and fisheries of Indonesia, Philippines and Vietnam (referred to here as domestic fisheries) are potentially managed through the SKJ MP. The tropical longline (TLL) fisheries are potentially managed through the BET MP and the southern longline fisheries (SLL) potentially managed through the SPA MP. There is no specific YFT MP, but the YFT stock will be indirectly managed by catches resulting from fishery settings provided by the SKJ, BET and SPA MPs. Fisheries in archipelagic waters are not managed through the MPs.

Understanding the potential impacts of MP selection on stocks requires the calculation of mixed-fishery performance indicators. For example BET is caught by fisheries that would be managed by the SKJ, BET and SPA MPs. When selecting the SKJ MP it may also be necessary to understand the potential impact on the BET stock. Additionally, the selection of the preferred BET MP may need to consider the potential impacts of the SKJ and SPA MPs on the BET stock. As there is no dedicated YFT MP, there will be a need for particular focus on the potential combined impacts of the SKJ, BET and SPA MPs on the YFT stock.

One of the main challenges for presenting and interpreting these indicators is the number of possible dimensions over which they can be calculated. For example, the indicators will be calculated over three time periods for many combinations of the single stock MPs. Additionally, some indicators can be calculated for different model regions and fisheries. This can result in a large volume of information that is difficult to interpret.

The purpose of the indicators is to support the selection of the preferred MPs. Given the potentially large amount of information that can be calculated with the mixed-fishery performance indicators it will be important to only focus on the key interactions between the different single stock MPs. As such, not all of the indicators presented here will be useful and need not be considered further.

Ideally, it will be necessary to evaluate all combinations of candidate SKJ, BET and SPA MPs in the multi-species modelling framework. However, given the amount of time it takes to run the evaluations it may be better to focus on combinations of smaller subsets of the candidate single stock MPs, i.e. after an initial round of filtering using only the single stock indicators.

In this report, the multi-species modelling framework presented in WCPFC-SC17-2021/MI-WP-05 (Scott et al., 2021) is used to run evaluations for SKJ, BET and YFT, using a range of SKJ MPs and BET MPs. Dynamic BET MPs are not yet developed and alternative constant future fishing scenarios for the TLL fisheries are used instead. SPA is not included in these evaluations but work has progressed for its inclusion in the multi-species modelling framework (Scott et al., 2022a). These evaluations are a test run and should be thought of as exploratory.

2 Modelling framework

The evaluations are run across grids of 96 SKJ, 96 BET and 144 YFT operating models (OMs) using the framework described in Scott et al. (2021). Each combination of SKJ MP and BET MP scenario is run for 960 iterations across the OM grids.

The SKJ MPs presented here all have the same data collection and estimation method, and differ only through the harvest control rule (HCR) (Scott et al., 2022b). In the SKJ models, all fisheries are managed through the SKJ MP (purse seine, pole and line and domestic fisheries) or are in archipelagic waters and not managed by an MP. This means that the SKJ evaluations can be run independently of the YFT and BET evaluations. The associated fishing effort of each of the fisheries managed through the SKJ MP is then transferred to the BET and YFT models.

In the evaluations presented here there is no dynamic BET MP, i.e. one that sets fishing opportunities for the TLL fisheries based on the stock status of BET. Instead, three scenarios for the level of BET catch by the TLL fisheries are evaluated: status quo (average of 2016-2018), status quo +15%, and status quo -15%. The associated fishing effort to take these BET catches by the TLL fisheries is transferred to the YFT models using the multi-species modelling framework (Scott et al., 2021). In this report these TLL scenarios are referred to as BET MPs as they reflect alternative behaviours of the TLL fisheries that would be managed through a BET MP.

As mentioned above, SPA is not considered in these evaluations and there is no SPA MP. Under the mixed-fishery approach the SPA MP would set fishing opportunities for the SLL fisheries. Here, the future catches of YFT and BET by these fisheries are fixed at the average 2016-2018 levels.

The catches of SKJ by the longline fisheries is small and is not considered in these evaluations, i.e. the effort made by the TLL fisheries in the BET OMs is not transferred to the SKJ OMs.

3 Indicators calculated

Four mixed-fishery performance indicators are calculated:

- Probability of SB/SBF=0 falling below the Limit Reference Point;
- Expected SB/SBF=0;
- Expected catches; and

- ‘Impact’ of each MP on each stock.

The expected catches can be calculated for different fishery segments and in different model regions.

The ‘impact’ attempts to quantify the impact of the fisheries managed through each MP on each stock. This is calculated by partitioning the contribution to the reduction in stock spawning potential (equivalent to 1 - SB/SBF=0) by fishery. This is similar to the calculation of the impact plots seen in the stock assessment reports (e.g. Castillo Jordan et al. (2021)). The impact contributions from the fisheries managed through each MP are then summed to calculate an overall impact of that MP. For example, the impact of the SKJ MP includes the combined impacts of the controlled purse seine, pole and line and domestic fisheries.

It should be noted that the current calculation of the impact indicator does not separate out the components of fisheries that operate in archipelagic waters. Consequently, the calculated impacts are not just of the fisheries managed through each MP, but of the archipelagic components of those fisheries too. For example, the impact of the SKJ MP also includes the impacts of the purse seine fisheries operating in archipelagic waters. If this impact indicator is thought to be useful it may be possible to also separate out the impact of fisheries operating in archipelagic waters, although this may require significant extra work.

Each indicator is calculated for each evaluation iteration and for each combination of SKJ and BET MP. The average value over three time periods: short- (2022-2030), medium- (2031-2039) and long-term (2040-2048), is calculated for each iteration, similar to the single stock indicators (Scott et al., 2018).

4 Results

4.1 The skipjack MPs

As mentioned above, all the SKJ MPs in this analysis have the same the same data collection and estimation method and only differ through the HCR (Figure 1). They are a subset of current candidate HCRs (Scott et al., 2022b). HCR 3 can be thought of as the least conservative HCR, with high catches even at low SB/SBF=0 levels. HCR 4 is the most conservative HCR. The output of the HCRs is a multiplier that is applied to the 2012 fishing effort (purse seines) or catches (the other fisheries managed through the SKJ MP).

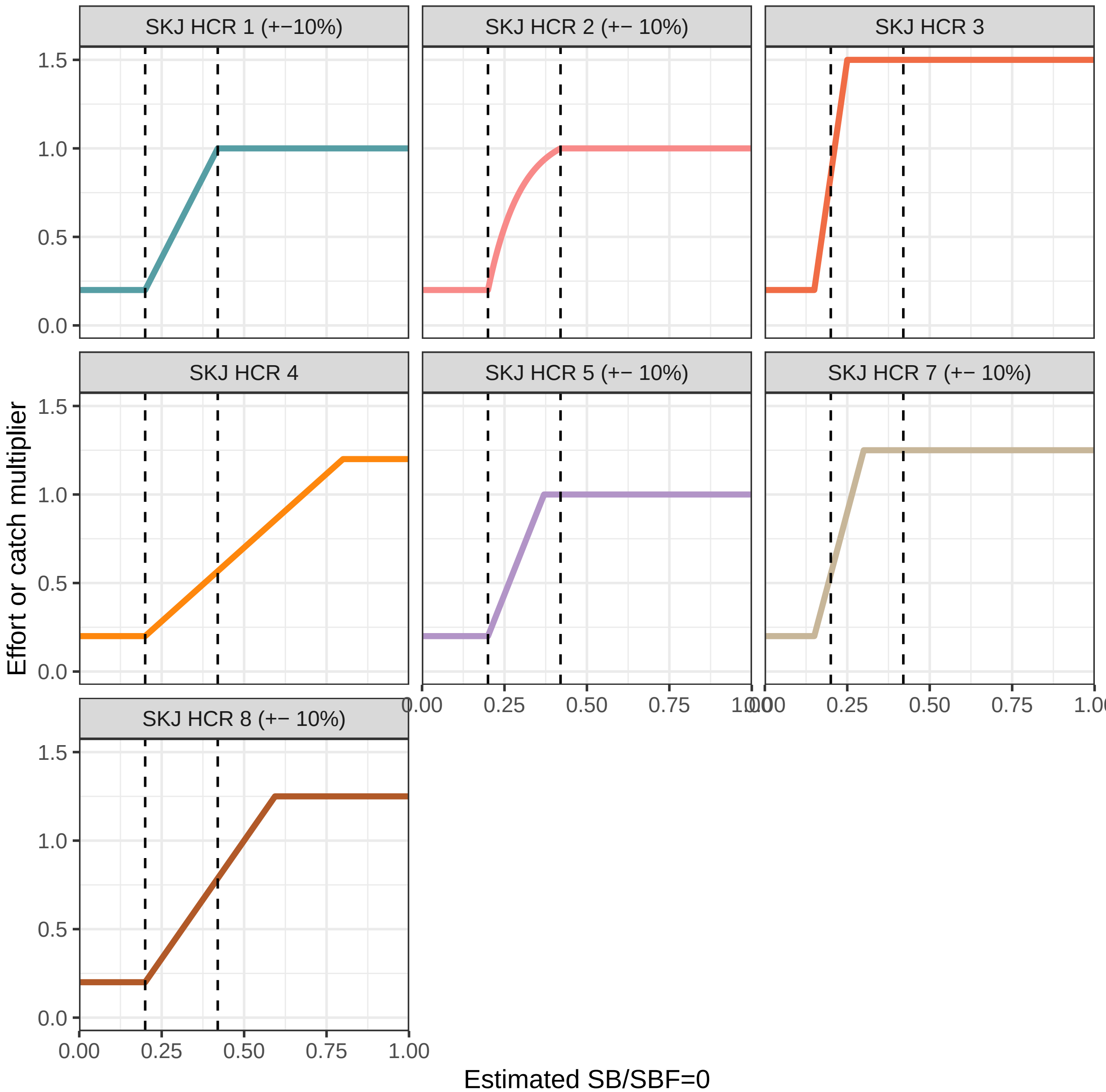

Figure 1: The SKJ harvest control rules. The Limit Reference Point (0.2) and the average 2012 level of SB/SBF=0 from the 2019 stock assessment (0.42) are shown as dashed horizontal lines. The output multiplier is applied to 2012 levels of catch or effort, depending on the fishery.

4.2 Probability of SB/SBF=0 being above the Limit Reference Point

The probability of the SB/SBF=0 being above the Limit Reference Point (LRP) of 0.2 for each stock and each SKJ HCR and BET MP combination is shown in Figure 2. There is a WCPFC requirement that an adopted harvest strategy has a probability of at least 0.8 of being above the LRP.

The stock status of SKJ is unaffected by the choice of the BET MP TLL scenario as SKJ are not taken by the TLL fisheries.

The probability for BET being above thte LRP is affected by the different combinations of SKJ HCR and BET MP. For example, the combination of SKJ HCR 3 and BET MP TLL SQ+15% produces the highest level of fishing on the BET stock and leads to a probability of BET being above the LRP of just above 0.8.

YFT stock status is less affected by the different combinations of SKJ HCR and BET MP and the resulting fishing levels and the probability of being above the LRP is always close to 1 even when the fishing pressure is high.

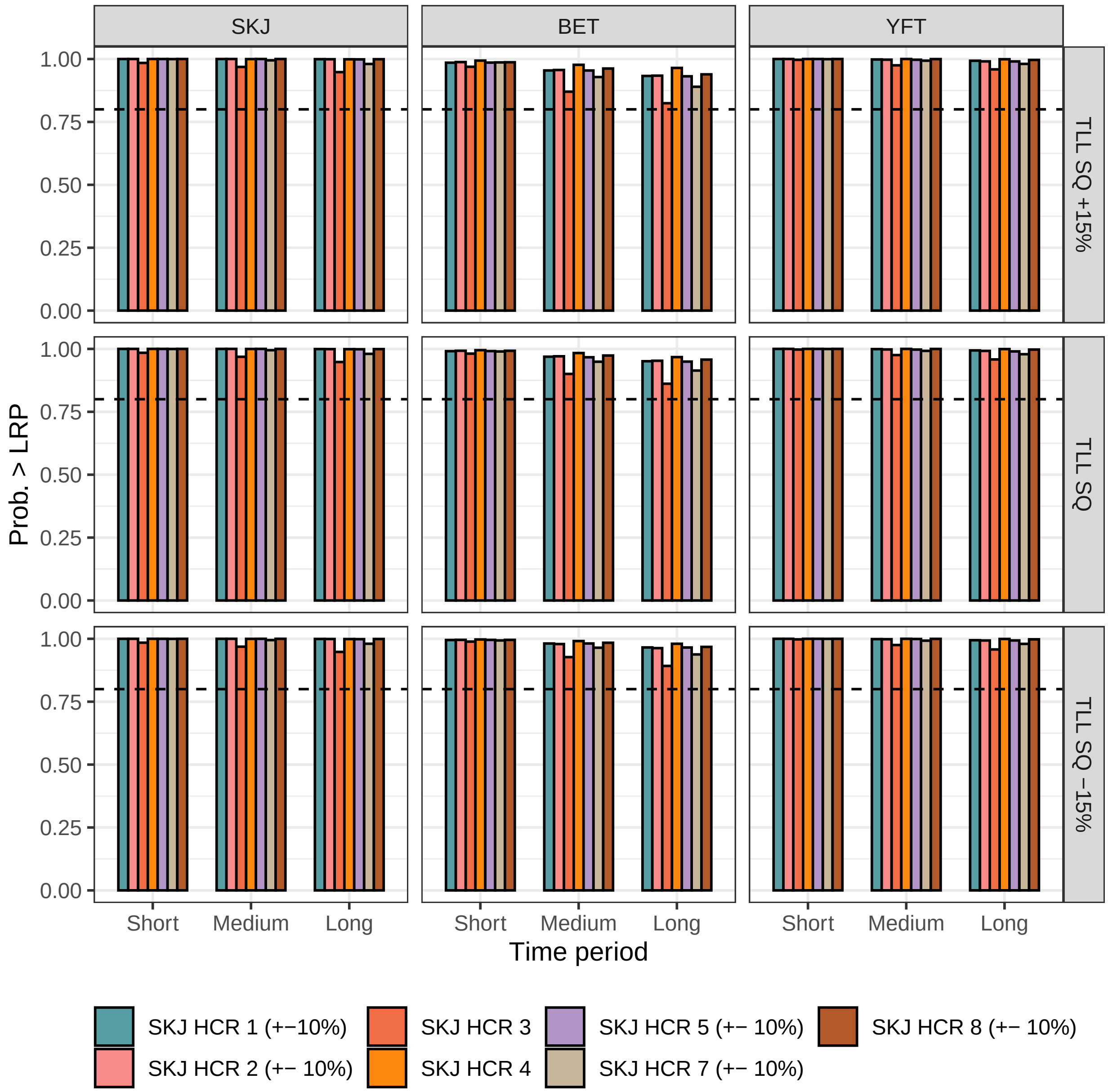

Figure 2: Probability of the SB/SBF=0 being above the Limit Reference Point (LRP) for each stock, each time period, and for each SKJ MP and BET MP combination. The different stocks are shown in the columns. The different BET MP options (TLL SQ+15%, TLL SQ, and TLL SQ-15%) are shown in the rows. The different SKJ HCRs are shown as the coloured bars.

4.3 SB/SBF=0

The SB/SBF=0 of each stock and each SKJ HCR and BET MP combination is shown in Figure 3. As noted above, the stock status of SKJ is unaffected by the choice of the TLL scenario as SKJ are not taken by the TLL fisheries.

There are currently no TRPs for BET and YFT. The interim objective for these stocks, as noted in CMM 2018-01, is to maintain the SB/SBF=0 at or above the 2012-2015 average (0.41 and 0.59 for BET and YFT respectively, Hare et al. (2021)). These values are shown in the plots.

As noted above, the SB/SBF=0 of BET has a small chance of falling below the LRP of 0.2 under SKJ HCR 3 and BET MP TLL SQ+15%. YFT is less affected by the choice of SKJ HCR and BET MP and the SB/SBF=0 is consistently well away from the LRP (see also Figure 2).

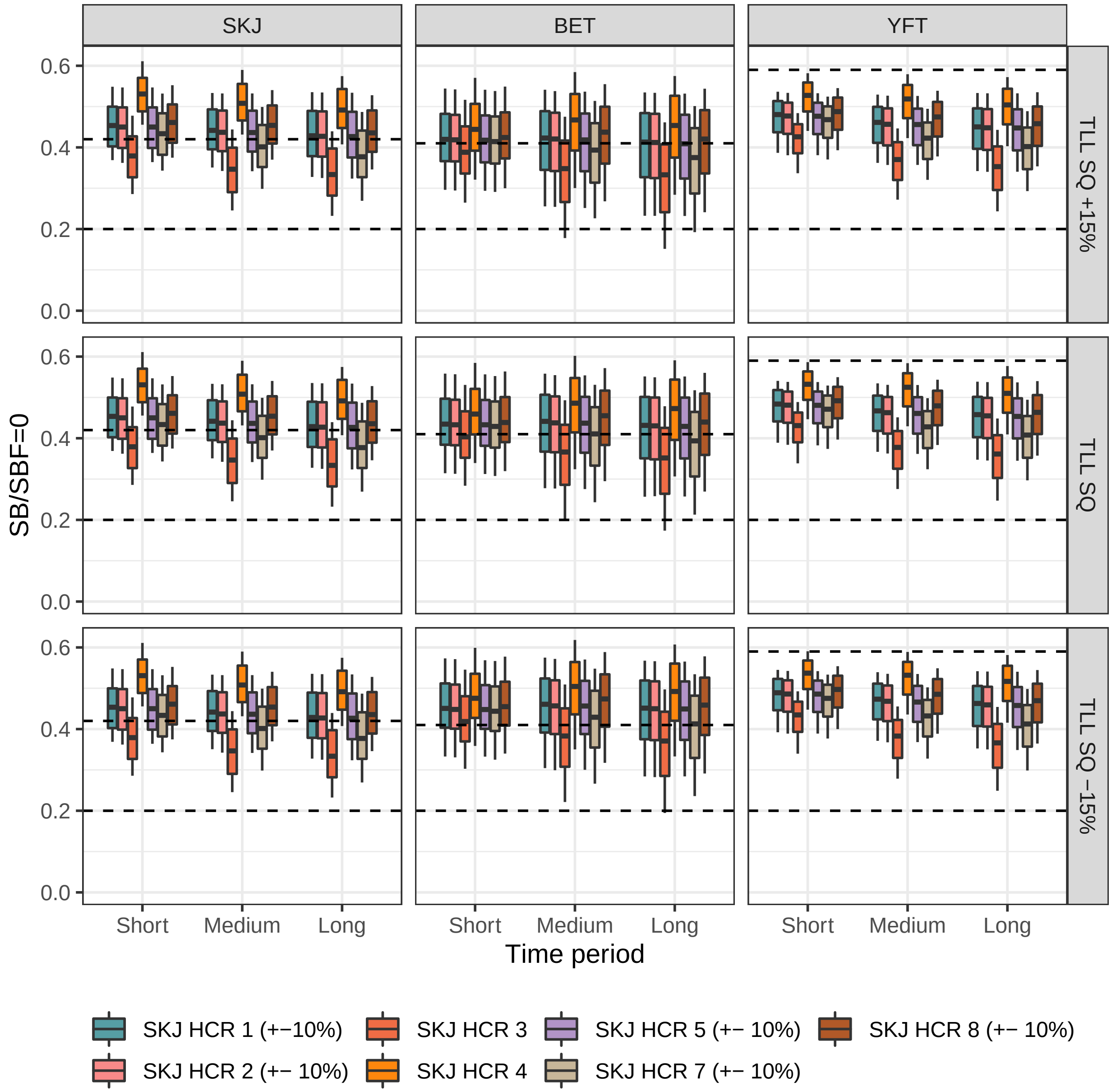

Figure 3: Box plots of the SB/SBF=0 for each stock, each time period, and for each SKJ MP and BET MP combination. The different stocks are shown in the columns. The different BET MP options (TLL SQ, TLL SQ-15% and TLL SQ+15%) are shown in the rows. The different SKJ HCRs are shown as the coloured box plots. The whiskers show the 80th percentile range, the box shows the 50th percentile range and the black line shows the median. The average 2012 level of SKJ SB/SBF=0 from the 2019 stock assessment (0.42) and the interim objectives for BET and YFT are shown as dashed lines. The LRP is also shown.

4.4 Catches

It is possible to calculate the catches of the stocks for different fishery groupings and model regions. This presents a very wide range of options for viewing the data, not all of which will help with the selection of preferred MPs.

Some examples of how the catch levels reflect the mixed-fishery interactions are shown here.

In the multi-species modelling framework the SKJ MP sets the fishing effort of the purse seine fisheries. These fisheries also take BET and YFT, the catches of which will be determined not only by the choice of SKJ MP (HCR), but also by the choice of the BET MP. When the BET MP is more conservative, for example the TLL catches are held at 15% lower than status quo levels (TLL SQ-15%), there is less pressure on the BET stock from these fisheries than with the other BET MPs. This enables the same amount of purse seine effort to catch more BET. This effect can be seen in Figure 4, where the BET MP TLL SQ-15% consistently results in higher catches of BET for the purse seine fisheries, although the difference is relatively small (note that only a subset of the SKJ HCRs are shown).

The combined impact on YFT catches of the choice of SKJ and BET MP is less straightforward. For example, when the SKJ MP has a less conservative HCR, such as SKJ HCR 3, the fishing effort on YFT and BET by the purse seine, pole and line and domestic fisheries will be higher than under the other SKJ HCRs. As the BET stock is being fished harder by the SKJ MP fisheries, the TLL fisheries must make more effort to take the same BET catch limit set by the BET MP from the slightly more depleted BET stock. This results in increased fishing effort on the YFT by both the purse seine and the TLL fisheries.

Purse seine fisheries have a bigger impact on the YFT stock than TLL fisheries and take larger catches. As expected, a less conservative SKJ HCR results in higher catches of YFT by the purse seine fisheries. The knock-on effect is slightly lower catches of YFT by the TLL fisheries, despite the TLL fishing effort increasing due to the lower biomass that results. The catches of YFT from unassociated purse seine and TLL fisheries are shown in Figure 5 as an example. The situation is reversed when a conservative SKJ HCR, such as HCR 4, is used with lower purse seine catches of YFT but higher TLL catches.

These interactions illustrate the combined impact on the YFT stock of the SKJ and BET MPs.

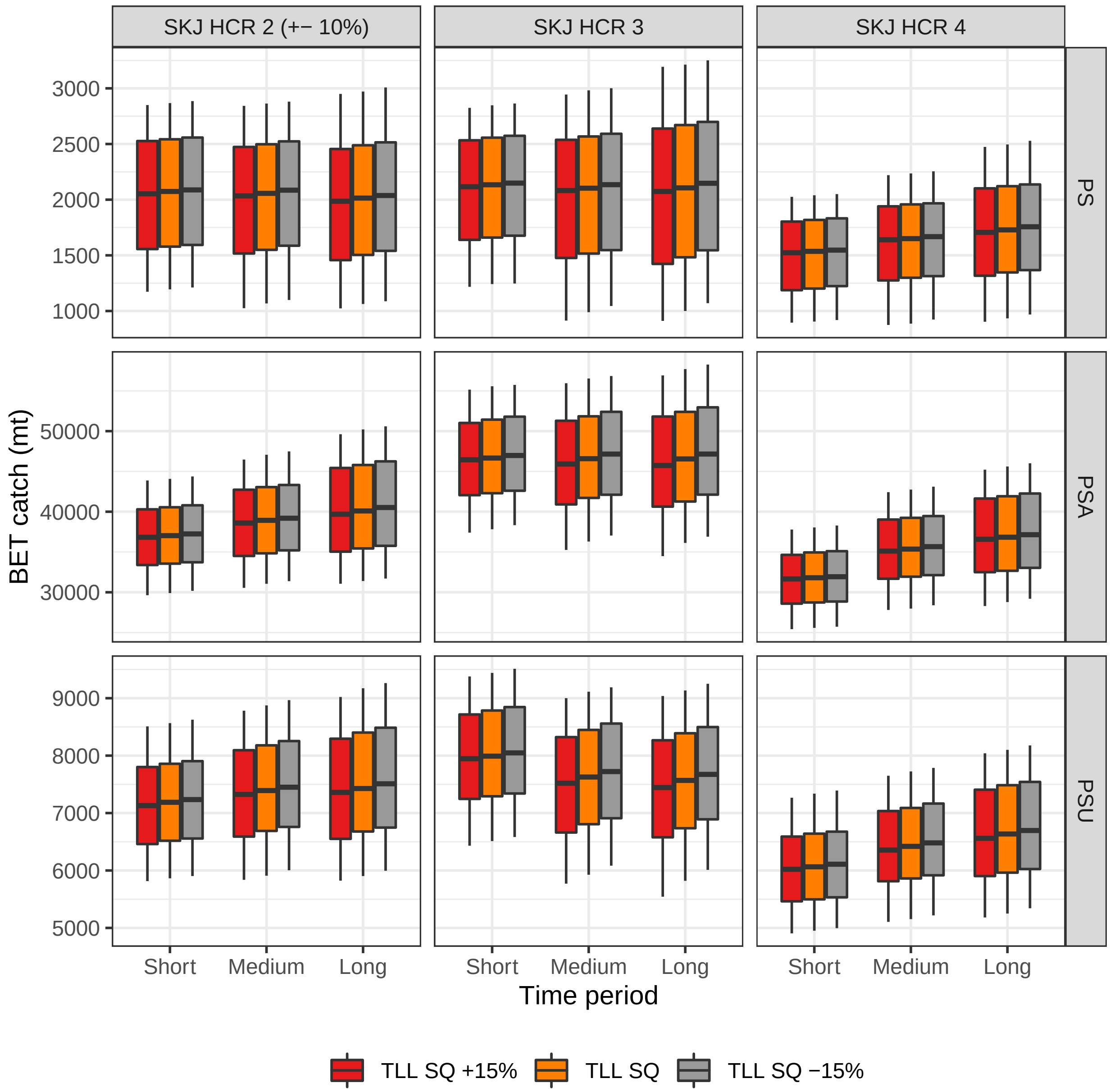

Figure 4: Catches of BET by the purse seine fisheries (associated - PSA, unassociatd - PSU and not specified - PS) in each time period. Each column is a SKJ HCR, each row is a fishery. The different BET MP options are shown as coloured box plots. The whiskers show the 80th percentile range, the box shows the 50th percentile range and the black line shows the median.

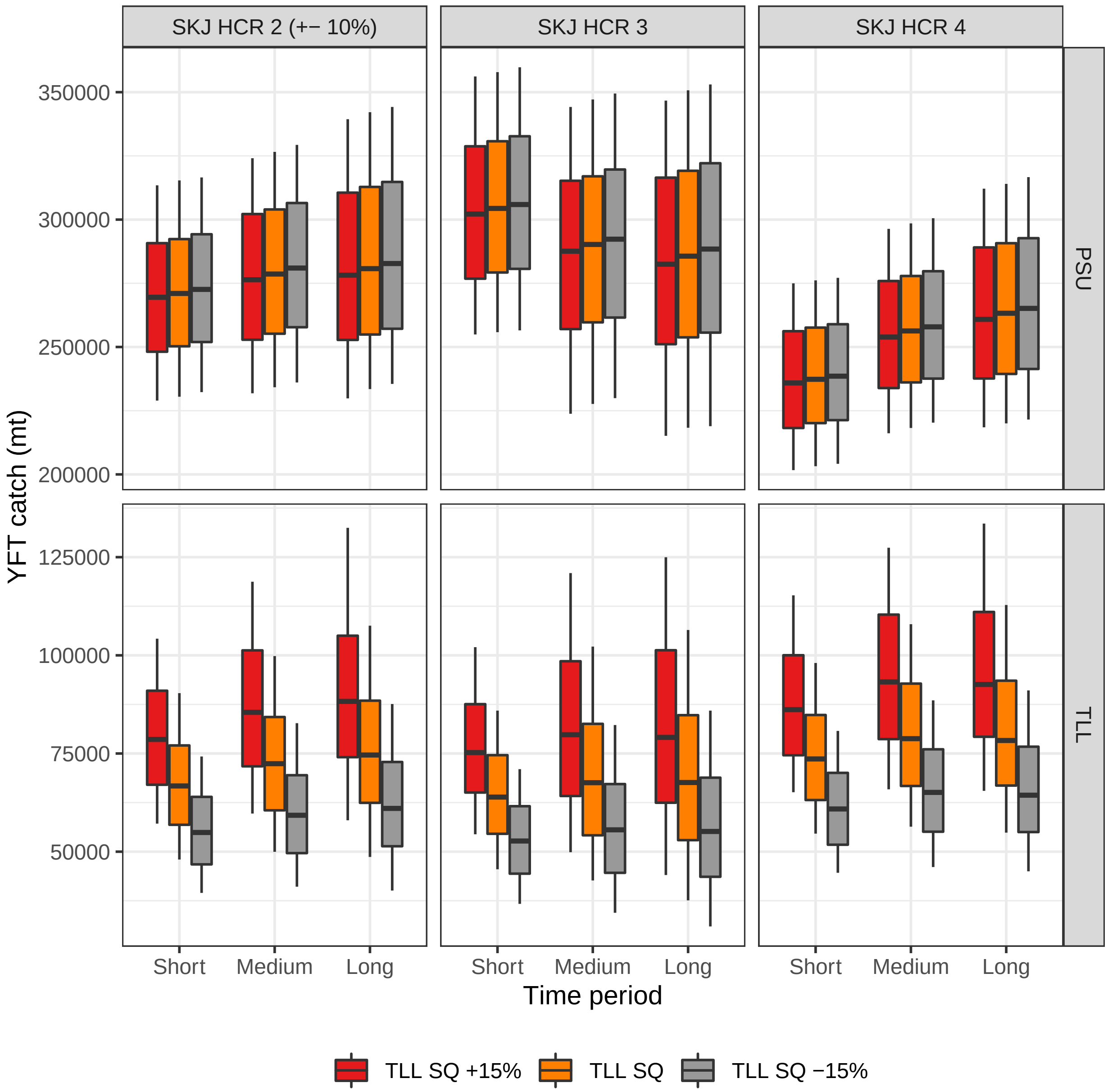

Figure 5: Catches of YFT by the TLL and the unassociated purse seine fisheries. Each column is a SKJ HCR, each row is a fishery. The different BET MP options are shown as coloured boxes. The whiskers show the 80th percentile range, the box shows the 50th percentile range and the black line shows the median.

4.5 Impact

Here, the impact on each stock is calculated for each single stock MP (SKJ, BET and SPA), across all combinations of SKJ and BET MP. The impact indicators therefore contain a lot of information which presents some challenges for presentation and communication. Some example plots are shown here.

Note that SPA is not considered in these evaluations. However, the SLL fisheries that would be managed through the SPA MP feature in the BET and YFT models. As mentioned above, the future catches of these fisheries are held at a constant status quo level. It is therefore possible calculate the impact of the fisheries that would be managed through the SPA MP.

The impact on the BET stock by the different MPs is determined by the different combinations of SKJ HCR and BET MP (Figure 6) (note only a subset of SKJ HCRs is shown). The SPA MP manages the SLL fisheries. It has very little impact on the BET stock as the catches of BET in the SLL fisheries are low. The SKJ MP (plus those fisheries in archipelagic waters) has a larger impact on the BET stock than the BET MP. A less conservative SKJ MP, such as one that uses SKJ HCR 3, leads to higher impacts from the SKJ MP. Similarly, a less conservative BET MP, such as BET MP TLL SQ+15%, results in a higher impact from the BET MP.

It should be noted that here the impacts are presented in a different way to that in the stock assessment reports. In the stock assessment reports, only a single model is considered (normally, the diagnostic case) and the impacts are presented as a stacked ribbon plot so that the cumulative impact can be seen. Here, 960 iterations are run for each SKJ HCR and BET MP combination and so the impact indicator has a range of values for each combination. Box plots are therefore used to reflect the range of values, rather than a stacked ribbon plot.

As mentioned above the impact plots do not separate the impact of archipelagic waters fisheries from the impact of the MPs.

The impact on the YFT stock by the different MPs is dominated by the choice of the SKJ MP (Figure 7).

Impact plots for SKJ are not shown. SKJ is fished only by the fisheries managed through SKJ MP plus the components of those fisheries operating in archipelagic waters. They are therefore responsible for the total impact on the SKJ stock.

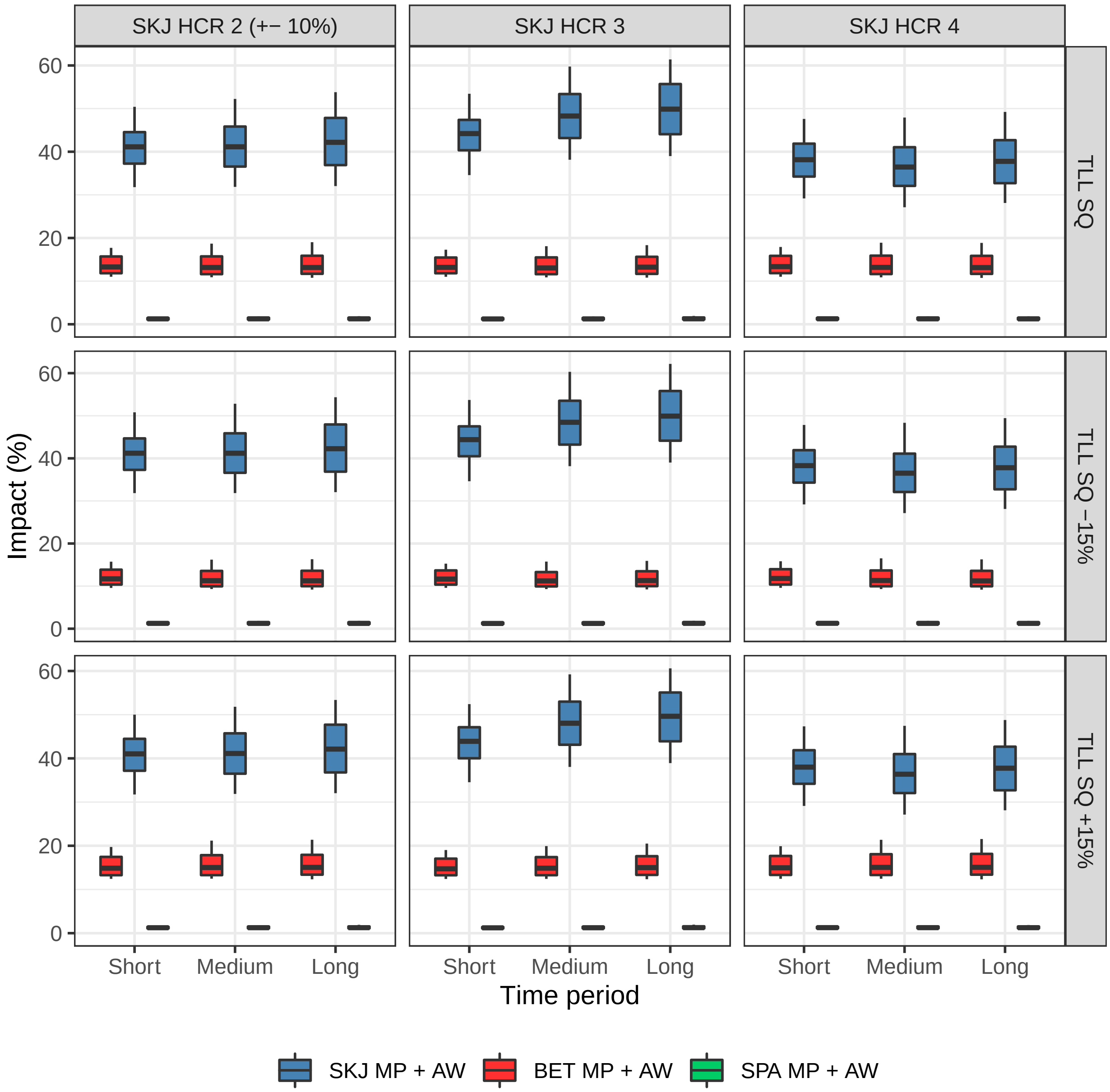

Figure 6: Impact of the different MPs (plus fisheries in archepelagic waters) on the overall BET stock by SKJ HCR and BET MP. Each column is a SKJ HCR and each row is BET MP. The boxes show the impact of the different MPs (plus fisheries in archepelagic waters). The whiskers show the 80th percentile range, the box shows the 50th percentile range and the black line shows the median.

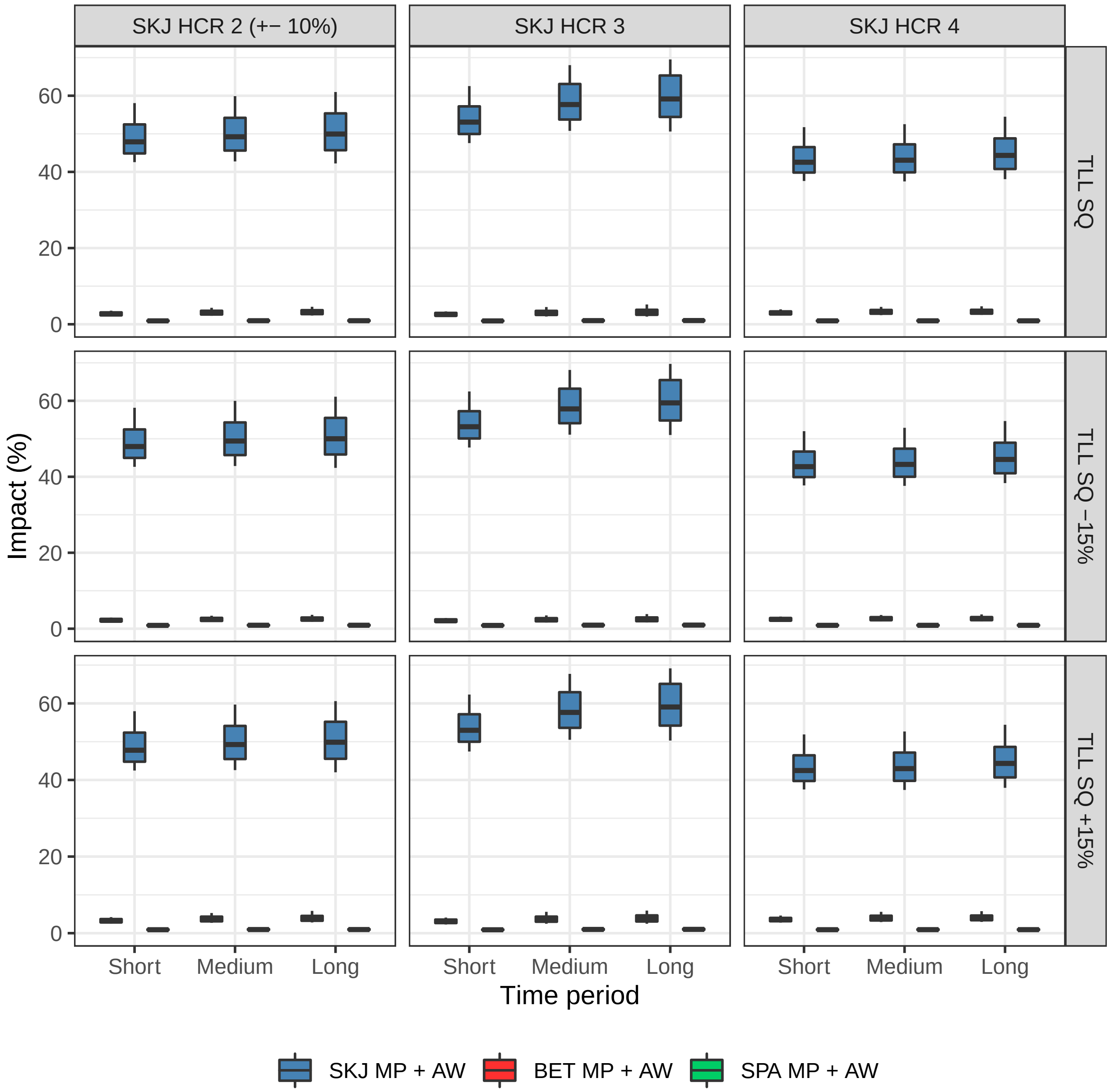

Figure 7: Impact of the different MPs (plus fisheries in archepelagic waters) on the overall YFT stock by SKJ HCR and BET MP. Each column is a SKJ HCR and each row is BET MP. The boxes show the impact of the different MPs (plus fisheries in archepelagic waters). The whiskers show the 80th percentile range, the box shows the 50th percentile range and the black line shows the median.

5 Summary

This report has described four mixed-fishery indicators that can be calculated for the different stocks using the multi-species modelling framework. Examples of these indicators has been shown for the SKJ, BET and YFT stocks for different combinations of SKJ and BET MPs.

A key consideration is how to present these indicators. In particular, the catch and impact indicators can be calculated over many different dimensions, e.g. different model regions and fisheries. This can make them challenging to present and interpret.

The role of the indicators is to support the selection of the preferred MPs. Careful consideration must therefore be given as to how useful these indicators are and how they can be best presented. If an indicator is unclear, or presents information that is difficult to interpret, then it should not be considered further.

Acknowledgments

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