COMMISSION
NINETEENTH REGULAR SESSION
Da Nang City, Vietnam
28 November to 3 December 2022

WCPO skipjack management procedure: dry run (SC18-2022-MI-WP03)– Information paper

WCPFC19-2022-11B
11 November 2022

This report was first presented to SC18 (as SC18-MI-WP-03) to provide an illustration of how a management procedure might be conducted by WCPFC. It reflects the discussions on harvest strategy implementation at that time. Following discussions at both SC18 and SMD01 aspects of the management procedure have been revised, in particular the switch to effort scaling for pole and line fisheries and the year ranges over which baselines for catch and effort are calculated. This document has not been updated to reflect these changes.

Changes to the document include:

- Addition of Table 4 showing the catch/effort scalar resulting from each of the five HCRs identified by SMD01 for consideration by WCPFC19. Table 4 shows the output of a trial MP run in 2022. It does not represent the scalars that would result from a skipjack MP adopted at WCPFC19 which would require the MP to be run in 2023.
- References to HCR 5 have been changed to HCR 2 to be consistent with the numbering of the updated PIMPLE (`https://ofp-sam.shinyapps.io/PIMPLE_WCPFC19/`)
- Minor text modifications to the abstract to improve clarity and readability.

SCIENTIFIC COMMITTEE
EIGHTEENTH REGULAR SESSION
Online
10–18 August 2022

WCPO skipjack management procedure: dry run.

SC18-MI-WP-03

23 July 2022

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Executive Summary

One of the key changes under the harvest strategy approach is that stock assessments routinely conducted for WCPO tunas will no longer be used as the basis for management. Instead, management action will be determined from a pre-agreed and tested management procedure. Full stock assessments will continue to be conducted under the harvest strategy approach, but they will be used primarily to monitor the performance of the adopted management procedure rather than as the basis for negotiations on future management, as is currently the case.

This document describes the hypothetical implementation of a management procedure for WCPO skipjack tuna in 2022. It considers the quality and availability of the data necessary to run the management procedure and the procedures for generating the inputs to the estimation model; it outlines the steps involved in running the estimation model, to determine an estimate of stock status, and the subsequent implementation of the harvest control rule; it considers how these data and other information might be used as part of a monitoring strategy to check the overall performance of the management procedure, and the new requirements of CCMs under the harvest strategy approach.

The estimation model was run successfully using data for the period 1972 to 2021. The availability and consistency (i.e. the magnitude and frequency of updates) of input data is considered to be good. Whilst a number of changes to data holdings and data availability have occurred in recent years none have been of sufficient magnitude to prevent the successful running of the estimation method.

For the purposes of this exercise we have assumed the use of a skipjack MP that includes HCR 2. The estimate of stock status ($SB_{latest}/SB_{F=0}$) in the terminal year of the estimation model is 0.54. If the management procedure was run this year this result would have set effort in the purse seine fishery and catches in all other fisheries at 2012 levels for the period 2023 to 2025.

Based on the analyses presented in this report, we make the following recommendations for the consideration of SC as part of the monitoring strategy:

- Some differences in model inputs are apparent but none are of sufficient magnitude to adversely impact the performance of the MP.
- Effort penalty terms for P-ALL-2 and SA-ALL-6 require further investigation to determine the most appropriate method for their calculation.
- The estimation model ran successfully and provided a reliable estimate of stock status that can be used as input to the HCR.
- Estimates of spawning potential depletion from the provisional 2022 stock assessment indicate that stock status remains within the bounds predicted by the MSE analyses.
- The results of the most recent stock assessment indicate the range of uncertainty included in

the OM grid remains appropriate.

- Ideally the stock assessment and the EM should be run in separate years, however, the additional workload associated with running the MP in non-assessment years should be considered.

1 Introduction

In accordance with the workplan for the adoption of harvest strategies under CMM2014-06, SC18 is scheduled to provide advice on the performance of candidate management procedures (MPs) for WCPO skipjack. A number of candidate MPs for skipjack have been proposed and tested, and are currently under consideration for potential selection at WCPFC-19. To assist understanding of how an MP might be implemented and how it would operate this paper presents a hypothetical 'dry run' analysis to illustrate the process of implementing an MP once adopted. It describes the procedure for running the MP and outlines a number of issues that could be considered as part of an ongoing monitoring strategy.

A management procedure comprises three main components; a data collection program that ensures that appropriate and sufficient information is available to monitor the stock and determine its status; an estimation method (EM) that follows a pre-specified and fixed procedure to determine the status of the stock; and a harvest control rule (HCR) that sets the management action to be applied given the estimate of stock status. The performance of the HCR is conditional on the stock status estimation method which in turn depends on the data collection program. Therefore, all three components should be considered as a whole when designing, evaluating and implementing a management procedure.

For the management procedures currently under consideration for WCPO skipjack, the data collection program and the estimation method are the same and each MP differs only in the form of the HCR. For the data collection program, we assume that the current system of data collection remains the same into the future and that catch and effort reporting, port sampling, observer monitoring, tag release and recapture programs, etc. continue to operate as they do at present. For the estimation model, each MP employs the same procedure to determine the status of the stock which is based on a fixed implementation of a MULTIFAN-CL assessment that has similar settings to those of the 2019 skipjack diagnostic case assessment model. In this paper, we outline the procedures for compiling the input files necessary to run the EM, we describe the model settings and phases of the estimation process and show how the results of the EM feed into the HCR to determine the future management of the fishery.

Input data for the EM will change over time due to the accumulation of new data as well as ongoing data management practices that may modify historical data holdings. In addition, inputs derived from model estimates (e.g. standardised CPUE indices) will be updated each time the EM is run and may also be subject to change over time. Changes in data over time can be important, as significant changes might represent a deviation from the conditions assumed when testing the MP. Some allowance for potential changes in input data has been included in the evaluation framework where, for example, observation error has been applied to the simulated catch and effort data, tag recaptures and size composition data that were used to test the MP and evaluate its likely performance. As part of the monitoring strategy it will be necessary to identify where significant changes to the input data have occurred and to consider whether these changes might constitute exceptional circumstances. Throughout this document we highlight instances where changes to the EM input data have occurred and in particular where those changes have not been foreseen in the MP testing process.

2 Estimation method input data

The EM is based on a fixed implementation of a MULTIFAN-CL assessment that has very similar structure and settings to the 2019 skipjack diagnostic case assessment model (Vincent et al., 2019b). Data inputs to the EM comprise fishery-specific catch, effort and length-frequency data for the period 1972 to 2021 and tag release and recapture data from a number of tuna tagging programs between 1977 and 2021. The quarterly temporal stratification and 8-region spatial stratification of the 2019 assessment has been retained as well as the fishery definitions that identify 31 relatively homogeneous fishing units representing purse-seine, pole and line and miscellaneous fisheries (gillnets, ringnets, handlines, etc.) as well as a number of long-line fisheries that are included in the model primarily to provide length composition information.

Many of the inputs to the EM were compiled as part of the work conducted to prepare the input data for this year's stock assessment of skipjack tuna (Teears et al., 2022; Castillo-Jordan et al., 2022). However, changes to the modelling approach for the skipjack assessment this year necessitated a number of additional analyses to ensure the EM inputs were generated in accordance with the procedures followed in 2019 and remain consistent with the conditions assumed in the testing and evaluation process.

2.1 Catch and effort data

Catch and effort data were compiled by year and quarter according to the fisheries defined in Vincent et al. (2019b) (Table 1). Catch for all fisheries was expressed in weight of fish, except for the longline fisheries for which a nominal catch of 500 individuals was set.

2.1.1 Purse seine

Purse seine catch for each set type (associated or unassociated) is determined from estimates of species composition from observer-collected samples raised to total catches estimated from raised log-sheet data (Hampton and Williams, 2016). For the Japanese purse seine fishery, for which there is greater confidence in species-based reporting, the reported catch is used directly.

For the most part, effort data for purse seine fisheries are defined as number of sets, specified by set type (associated and unassociated). However, in assessment regions 5 and 6 where there is insufficient effort in pole and line fisheries to conduct CPUE standardisations, time series of standardised CPUE are generated from purse seine fisheries.

In region 5, CPUE for the Philippines domestic purse seine fishery was analysed using general linear models following the same approach as Bigelow et al. (2019) to produce a standardised index of abundance for the S-ID-PH-5 fishery between 2005 and 2021. Estimates of time variant precision were implemented as time variant effort deviation penalties in MULTIFAN-CL.

In region 6, CPUE for the purse seine fishery operating largely within PNG archipelagic waters was analysed using GLMs following the approach of Vidal et al. (2019). These indices were applied to the catches of the SA-ALL-6 fishery for the period 1997 to 2021 with estimates of time variant precision implemented as time variant effort deviation penalties in MULTIFAN-CL.

2.1.2 Pole and line

Standardised CPUE indices were applied to pole and line fisheries in assessment regions 1,2,3,4,7 and 8. These standardised indices were estimated using spatio-temporal GLMs fitted to operational catch and effort data (Teears et al., 2022) and followed the same procedure as Kinoshita et al. (2019). The uncertainty in each pole and line CPUE estimate, by fishery and year-quarter, was incorporated into the model as time-variant penalty weights for the effort deviations.

The unit of effort for the pole and line fisheries of PNG and Solomon Islands (assessment region 6) and of the mostly Indonesian pole and line fishery in assessment region 5 was nominal fishing-vessel-day.

2.2 Size composition data

Length frequency data are included in the model and provide information on the size composition of the catch. The method employed for constructing size frequency data for purse seine fisheries, including weighting by catch for various set-type and spatial strata, was the same as that employed in previous years (Abascal et al., 2014; Vincent et al., 2019a). Samples were spatially weighted (5° x 5° squares) with thresholds applied to the maximum weighting value to ensure small samples do not overly influence model estimates.

Length frequency data for pole and line fisheries in assessment regions 1,2,3,4 and 7 are available from the Japanese offshore and distant water fleets throughout the assessment time series. Length frequency data for pole and line fisheries in assessment regions 5,6 and 8 are derived from observer data.

2.3 Tag release and recapture data

A substantial quantity of tag release and recapture data are available from 4 tagging programs (SSAP 1977-80, RTTP 1989-92, PTTP 2006-present and JPTP 1989-present). Procedures for compiling tag release and recapture data for the assessment are described in Peatman et al. (2022), including procedures for the adjustment of tag releases to account for tag loss that can occur as a result of tag shedding and tagging related mortality and to account for any non-usable recaptures due to a lack of adequately resolved recapture data. All procedures for compiling the tag release and recapture data were consistent with those followed for the 2019 skipjack stock assessment.

3 Running the estimation model

The estimation model is a simplified, fixed implementation of the 2019 skipjack stock assessment diagnostic case model and differs from a full stock assessment approach in a number of ways. A full stock assessment fits to the data over a number of assessment phases with initial parameter estimates set to default starting values. For the initial phases of the assessment many of the parameters are fixed and only a few are free to be estimated. With each successive phase more parameters are freed for estimation until the final phase when all parameters are freely estimated.

The estimation model takes a different approach. Rather than starting from default values it uses the estimates from the last stock assessment as a starting point and allows all parameters to be freely estimated from the outset. The model is fitted over three estimation phases. For the first phase the the catch errors penalty term (age flag 144) is set to a low value (100) allowing the model to have increased freedom to adjust to the new input data. For phases 2 and 3 the catch errors penalty is progressively increased (10,000, 100,000) so the model fits more closely to the observed catches. This approach reduces the number of phases necessary to fit the model but still allows it to adjust to the new input data and provide a reliable estimate of stock status. The development and testing of this EM formulation is detailed in Scott et al. (2020).

3.1 Model settings and estimation phases

Only a single estimation model is run. The settings of the estimation model are outlined in Table 2 with all other settings, except for the weighting for the catch likelihood, based on the settings of the 2019 assessment diagnostic case model.

The model is run over 3 estimation phases with all model parameters freely estimated in each phase. The only changes made to model settings between the phases is to progressively increase the catch errors penalty (as described above) and to set the number of function evaluations performed in each phase (100, 100, 1000).

3.2 Results and model diagnostics

The role of the EM is to provide a reliable and relatively unbiased estimate of stock status. In this instance, the skipjack EM is based on a stock assessment model and employs stock assessment software, however, the EM is effectively a fixed algorithm that is applied consistently in each management period without change. The settings of the EM have been determined to ensure that it performs adequately well over a broad range of scenarios and it is therefore unlikely to perform optimally for any one specific scenario. This should be kept in mind when interrogating model diagnostics

While the detailed interrogation of the estimation model diagnostics typically carried out as part of a formal stock assessment may not be necessary, it would be prudent to examine a number of key model outputs and diagnostics to ensure that the EM is performing well and is not subject to estimation failure. In this respect goodness of fit diagnostics such as the catch estimate deviates and effort deviates provide an overall indication of the performance and reliability of the estimation model. Similarly model estimates of fishery specific selectivity at age and time series of recruitment deviates can provide an indication of whether or not the model is performing to expectation (Merino et al., 2022).

There is no indication of significant failure of the estimation model from the diagnostics presented. Evidence of significant failure might include distinct departures of residuals from zero (or 1 depending on how they are calculated), strong persistent trends over time and model estimates (e.g. selection patterns) that show unreasonable results.

Observed and predicted catches (Figure 16) match well for all fisheries across the time series although some variability in catch deviates is apparent for the purse seine fishery in region 3 (S-ALL-3) towards the end of the time series. Similarly effort deviations (Figure 17) are centered around zero for all fisheries throughout the time series, although increased variability is apparent for the northern purse seine fisheries (S-ALL-1, S-ALL-2 and S-ALL-3). These fisheries have a strong seasonal fishing pattern resulting in a less clear catch and effort relationship. This issue is discussed further in Section 5 with reference to the monitoring strategy. Although more variable, effort deviations for these fisheries remain centered around zero and do not indicate a significant failure of the estimation model.

Time series of recruitment deviates (Figure 18) show some indication of long term temporal trends in some regions, but do not indicate significant failure of the estimation model. Similarly the estimated fishery specific selection patterns (Figure 19) appear to be well estimated and present no cause for concern. Overall, the estimation model diagnostics indicate that the model is performing well and is not subject to significant failure.

The maximum gradient of the estimated parameters is often used as a general indication of model convergence, however, it is not considered to be a useful indicator of performance of the estimation model. This is because the estimation model is run for a fixed and pre-specified number of function evaluations. Prior testing has shown that the estimation model can produce reliable and relatively unbiased estimates of stock status without being run to full convergence (Scott et al., 2020). To illustrate this point the estimation model was run to convergence in a further 4th phase achieving a maximum gradient of 9.86×10^{-4}. Following this 4th phase the maximum gradient had reduced considerably but the estimate of stock status in the terminal year remained almost identical to that of the 3 phase EM (Figure 20).

4 Applying the harvest control rule

Once the estimation model has been run and an estimate of stock status ($SB_{latest}/SB_{F=0}$) has been obtained the application of the HCR is a relatively straight forward process. The value of the scalar is determined corresponding to the estimated stock status and any additional meta-rules (e.g. that the value of the scalar cannot change by more than 10% from one management period to the next) applied. For this illustrative trial run we have selected HCR 2 (Figure 15) which has a maximum scalar of 1.0 and a sloping curve that progressively reduces fishing opportunities as the stock approaches the limit reference point (LRP). No additional meta-rules are applied.

The terminal estimate of stock status is measured as $SB_{latest}/SB_{F=0}$ where SB is the spawning potential biomass in the final year of the assessment and $SB_{F=0}$ is the average of the spawning potential biomass over the 10 preceding years (with a lag of 1 year, i.e. the last year of the assessment is not included). The estimate of $SB_{latest}/SB_{F=0}$ from the estimation model is 0.54 and the corresponding scalar from the HCR is 1.0 (Figure 15).

If the management procedure was being run this year (2022), this would set effort in the purse seine fisheries and catches in all other fisheries at 2012 levels for the subsequent management period (2023 to 2025). The management procedure would be run again in 2025 to set the level of fishing in 2026 to 2028.

5 Monitoring strategy considerations

The monitoring strategy routinely evaluates the performance of the MP to check that it is working as expected. The monitoring strategy should consider all aspects of the harvest strategy including procedures for evaluating and testing the MPs; the scenarios that should be included in the OM grid; the preparation and application of the EM and the performance of the management procedure as a whole. In addition, it may identify changes in the dynamics of the fishery resulting from environmental, economic or social factors that may require a reconsideration of the management objectives and the testing of alternative MPs.

In this report we focus on aspects of the monitoring strategy relating to the application of the MP. We consider the consistency of data availability and the procedures for compiling and running the EM. Of primary concern is the consistency with which the actual implementation of the MP corresponds to the simulated conditions under which the MP was tested.

5.1 Consistency of the EM inputs with the assumptions of the evaluations

Many of the inputs to the EM are the same as those required for the full stock assessment. Consequently the generation of the EM inputs ran concurrently with work to generate the inputs for the full stock assessment of WCPO skipjack (also presented to this SC (Castillo-Jordan et al., 2022)). However, a number of structural changes have been made to this year's skipjack assessment and many of the EM inputs (CPUE standardisation, effort penalty terms, tag reporting rate priors, etc.) had to be either calculated separately or back transformed from the assessment inputs so that they remained consistent with the approaches and formats assumed under the evaluation of the MPs.

As noted above, some change in data inputs is to be expected either due to ongoing data management processes or because inputs generated from model estimates (e.g. standardised CPUE) will be updated with the addition of new data. For the most part, however, the inputs to the EM showed very good consistency with previous inputs and with the conditions assumed under the evaluation framework. Some differences were apparent in the historical catch data and in the historical tag release and recapture data (see below). In addition it was not possible, with the time available, to replicate some inputs for the effort penalty terms. This issue would be resolved prior to any actual implementation of the EM.

5.1.1 Data availability

As a whole, the data collection program has performed as anticipated and all necessary data to run the EM are available, with just one minor caveat. Effort data for pole and line fisheries in 2021 were not available due to reduced data entry manpower as a consequence of COVID-19. To resolve this issue, quarterly effort values for 2021 were generated from interpolation of the historical catch-effort relationship for each of the pole and line fisheries (Figure 9). A sensitivity analysis was conducted to determine the impact of using either interpolated values or simply setting the values to missing. The model shows some sensitivity to this assumption (Figure 21) with the missing values option estimating a less depleted stock status. Interpolated effort values have been used in the final run of the EM.

5.1.2 Historical data revisions

Comparison of the catch values used in the MSE framework for testing the MPs and the 2022 inputs to the EM for purse seine and pole and line fisheries (Figures 2 and 3) generally show good consistency in the catch estimates. Some differences are apparent for the purse seine fishery in assessment region 2 (S-ALL-2) for which a strong seasonal pattern in catches is apparent. Catch and effort data for Japanese coastal fisheries was revised following the last assessment and updated to reflect a more appropriate seasonal and spatial distribution of fishing. As a consequence, fewer catch records in quarters 1 and 4 are represented in the data extraction. To facilitate the construction of the input files necessary to run the EM, catch observations for these missing periods were replaced with very low catch values so as to retain the format and structure of the historical catch and effort information. Catches during these quarters are very small and their inclusion or omission does not impact the EM estimate of stock status.

Differences in catches are also apparent for the purse seine fishery in assessment region 5 (S-ID-PH-5) for which catch estimates between 1990 and 2010 have reduced. A sensitivity analysis was conducted to determine the impact of this change in historical catch (Figure 21) and showed minimal impact on the EM estimate of stock status.

5.1.3 Standardised CPUE revisions

Standardised indices of abundance are generated for pole and line fisheries in regions 1,2,3,4,7 and 8 and also for purse seine fisheries in regions 5 and 6. In most cases, the updated indices show good correspondence to the values assumed in the evaluation framework. Some differences are apparent for the pole and line fisheries in regions 1 and 2 (P-ALL-1 and P-ALL-2) which potentially also result from the data revisions described above.

From the information available it was not possible to reproduce the effort penalty terms for the pole and line fishery in region 1 (P-ALL-1) and the purse seine fishery in region 6 (SA-ALL-6). In both instances, the original values from the 2019 assessment have been retained pending further investigation into this issue.

5.2 Monitoring stock status

A key input to the monitoring strategy will be the updated full stock assessment which will provide estimates of stock status based on the most recent data and the best available science. The full stock assessment is an important benchmark against which aspects of the harvest strategy should be judged. However, direct comparison of the results of the EM and the stock assessment would not be appropriate since they each perform different roles under the harvest strategy approach.

The results of the stock assessment should be used to check that stock status remains within acceptable bounds and is not deviating from the levels anticipated from the MSE testing process. In addition the full stock assessment will provide information on the sources of uncertainty included in the OM grid and can be used to identify any gaps in the range of scenarios that are used to evaluate the performance of candidate MPs.

A comparison of the expected performance of the MP and the most recent stock assessment results in terms of spawning potential depletion (Figure 22) shows good correspondence in the terminal estimate from the stock assessment and the results of the MSE analyses, but show less overlap of the estimates from the assessment and the MSE analyses throughout the time series. This may suggest there is still some uncertainty not accounted for in the evaluation framework. We make this comparison with a cautionary note, realising that the stock assessment results are provisional and have yet to be formally reviewed by SC18.

5.3 Monitoring strategy recommendations

Based on the information provided above, we make the following recommendations for the consideration of SC as part of the monitoring strategy.

- Some differences in model inputs are apparent but none are of sufficient magnitude to adversely impact the performance of the MP.
- Effort penalty terms for P-ALL-2 and SA-ALL-6 require further investigation to determine the most appropriate method for their calculation.
- The estimation model ran successfully and provided a reliable estimate of stock status that can be used as input to the HCR.
- Estimates of spawning potential depletion from the most recent stock assessment indicate that stock status remains within the bounds predicted by the MSE analyses.
- The results of the most recent stock assessment indicate the range of uncertainty included in the OM grid remains appropriate.
- The additional workload associated with running the MP in non-assessment years should be considered.

6 Discussion

The results of the 2022 stock assessment became available only very recently and there was insufficient time to conduct a thorough investigation of the results and to determine how these might inform decisions on the models to be included in the OM grid. The estimates of the stock assessment are more positive than those of the MSE analyses and suggest a less depleted stock in the historical period. However terminal estimates of the stock assessment are closer to those of the MSE analyses.

6.1 Estimation model considerations

To the extent possible the EM should provide a reliable and relatively unbiased estimate of stock status. Appropriate model settings for the EM should be selected to achieve this basic criteria. The EM investigated here is based on the model settings of the 2019 diagnostic case. Although it is quite possible that alternative model settings would also achieve these basic criteria, it is not necessary to test all possible EM scenarios unless one is expected to significantly outperform the others.

It is, however, very important that the EM and its settings do not change through time. This is because the performance of each MP will have been evaluated under the assumption that a specific data collection program, estimation model and HCR will be applied throughout the evaluation time period. Changes to any component of the MP will mean that the MP being applied differs from the one that was tested. This of course does not mean that, once adopted, an MP cannot be changed. But, in such cases where it is considered necessary to change a component of the MP (data collection, EM, HCR), the revised MP should be re-evaluated to ensure that it continues to represent the best performing candidate with regards to achieving management objectives.

Throughout this paper we have noted that the MP comprises a data collection programme, an EM and an HCR. Although we may test a large number of alternative HCRs, it is most likely that only a small number of EMs and data collection scenarios would be considered. This is because the primary role of the EM is to provide a reliable and relatively unbiased estimate of stock status to inform the HCR. Alternative EMs may be considered if they are expected to significantly outperform the current EM with respect to the estimation of stock status. Similarly alternative data collection programmes may be considered if they are believed to be plausible alternatives and likely to significantly impact the performance of the EM.

Ultimately, the performance of the EM is part of the performance of the MP as a whole. If the MP overall is judged to be effective based on the results of the MP testing through MSE, then the EM that forms part of that MP can also be considered to perform effectively.

6.2 Logistical considerations

The generation of inputs to run the estimation model can be an intensive process. Even though similar procedures to previous years have been followed and automated data extraction scripts and existing data processing protocols have been employed, there remains a significant amount of work in compiling and checking the model inputs. In addition to the SSP, Japanese and US scientists also conduct analyses for the generation of model inputs which would be required when running the stock assessment and when running the EM.

The work this year to generate the model inputs ran concurrently with work to generate inputs for the full stock assessment, but this is not ideal. Preferably, the full stock assessment and the MP would be run in different years to provide a more defined separation between the processes of running the MP to set new management levels, and running the full stock assessment to monitor the performance of the MP. This does, however, entail a greater workload for generating the inputs and should be taken into consideration when determining the schedule for running the MP.

7 Conclusions

Sufficient data were available to generate the necessary inputs to run the EM and to apply the MP. Some changes to historical data are apparent but are not of sufficient magnitude to prevent the running of the EM or to invalidate the results. Penalty terms for some fisheries cannot be reproduced and further work is required to resolve this issue, however, sensitivity analyses indicate this has minimal impact on the estimation of stock status and does not invalidate the results of the EM.

The EM ran successfully and returned an estimate of spawning potential depletion ($SB_{latest}/SB_{F=0}$) in the terminal year (2021) of 0.54. Assuming the application of HCR 2 this would set effort in the purse seine fisheries and catch in all other fisheries to 2012 levels for the period 2023 to 2025.

The results of the most recent stock assessment indicate that stock status remains within the bounds predicted by the MSE analyses. Based on preliminary inspection, the results of the most recent assessment also indicate that the range of uncertainty included in the OM grid remains appropriate.

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A Tables

Table 1: Skipjack fishery definitions.

Gear	**number**	**category**	**Code**	**Flag**	**Region**
Pole and line	1		P-ALL-1	ALL	1
Purse seine	2	combined	PS-ALL-1	ALL	1
Longline	3		LL-ALL-1	ALL	1
Pole and line	4		P-ALL-2	ALL	2
Purse seine	5	combined	PS-ALL-2	ALL	2
Longline	6		LL-ALL-2	ALL	2
Pole and line	7		P-ALL-3	ALL	3
Purse seine	8	combined	PS-ALL-3	ALL	3
Longline	9		LL-ALL-3	ALL	3
Domestic	10		Z-PH-5	PH	5
Domestic	11		Z-ID-5	ID	5
Purse seine	12	combined	S-ID-PH-5	ID-PH	5
Pole and line	13		P-ALL-5	ALL	5
Purse seine	14	associated	PS-ASS-5	DW	5
Purse seine	15	unassociated	PS-UNASS-5	DW	5
Domestic	16		Z-VN-5	VN	5
Longline	17		LL-ALL-5	ALL	5
Pole and line	18		P-ALL-6	ALL	6
Purse seine	19	associated	PS-ASS-6	ALL	6
Purse seine	20	unassociated	PS-UNASS-6	ALL	6
Longline	21		LL-ALL-6	ALL	6
Pole and line	22		P-ALL-4	ALL	4
Longline	23		LL-ALL-4	ALL	4
Pole and line	24		P-ALL-7	ALL	7
Purse seine	25	associated	PS-ASS-7	ALL	7
Purse seine	26	unassociated	PS-UNASS-7	ALL	7
Longline	27		LL-ALL-7	ALL	7
Pole and line	28		P-ALL-8	ALL	8
Purse seine	29	associated	PS-ASS-8	ALL	8
Purse seine	30	unassociated	PS-UNASS-8	ALL	8
Longline	31		LL-ALL-8	ALL	8

Table 2: Skipjack estimation model settings.

Model setting	**Value**		
Region structure	**8 regions**		
SRR steepness	**0.8**		
Size comp. weighting	**100**		
Tag mixing period	**1 qtr**		
Growth	**Lmin=25.7051**	**Lmax=78.0308**	**k=0.212**
Hyperstability in CPUE	**0**		

Table 3: Data availability and preparation issues when constructing inputs to the EM and the recommended action to address the discrepancy. The impact score is a subjective measure of the degree to which the discrepancy affects the performance of the of the MP (on a scale of 0 - minimal impact to 5 critical impact).

Discrepancy	**Fishery**	**Impact**	**Action**
Catch data revisions	S-ALL-2	0	none
Catch data revisions	S-PH-ID-5	0	run sensitivity analyses
Effort data 2021 missing	P-ALL-1,2,3,4,7,8	1	run sensitivity analyses
Effort penalty calculation	P-ALL-1	1	further investigation
Effort penalty calculation	SA-ALL-6	1	further investigation

Table 4: Output (catch/effort scalar) from each of the 5 HCRs identified by SMD01 for consideration by the Commission for an estimated stock status of $SB/SB_{F=0} = 0.54$. Note that for the first application of the HCR no constraint has been applied i.e. the scalar applies directly to baseline catch and effort levels.

HCR	**output scalar**
1	1
2	1
5	1
6	1.05
9	1.08

B Figures

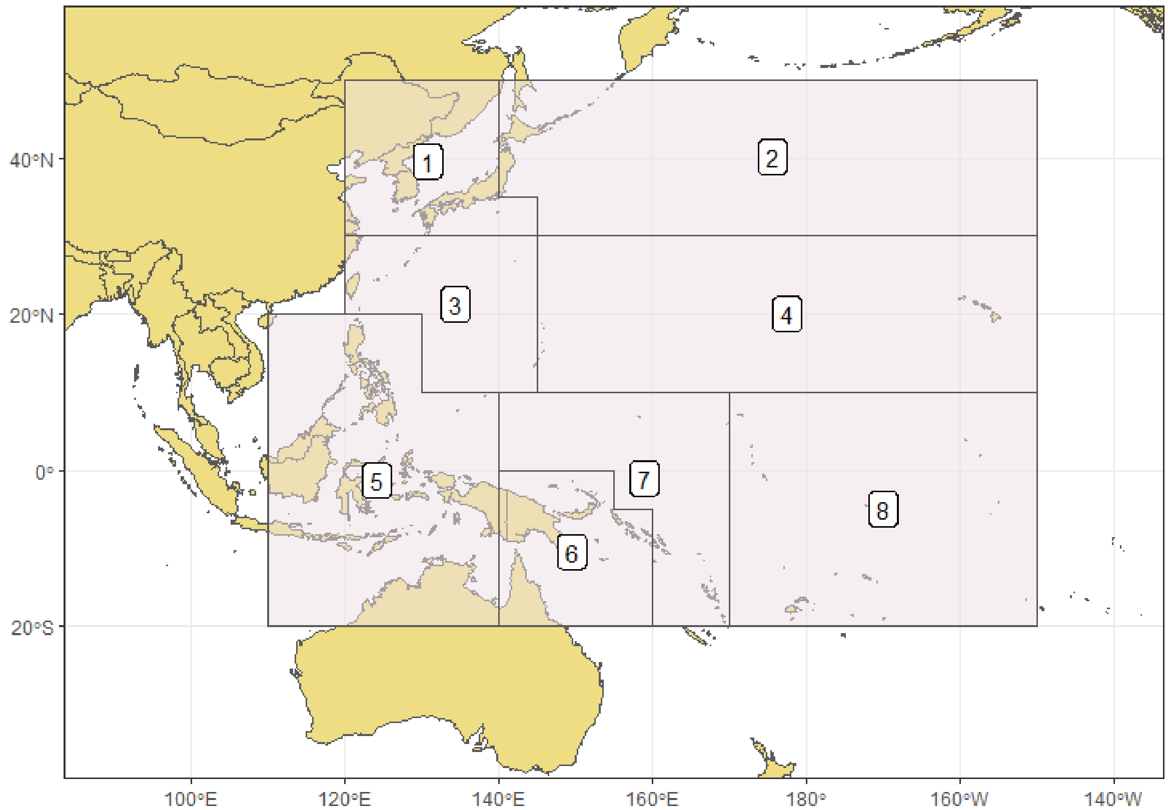

Figure 1: Regional structure of the skipjack estimation model.

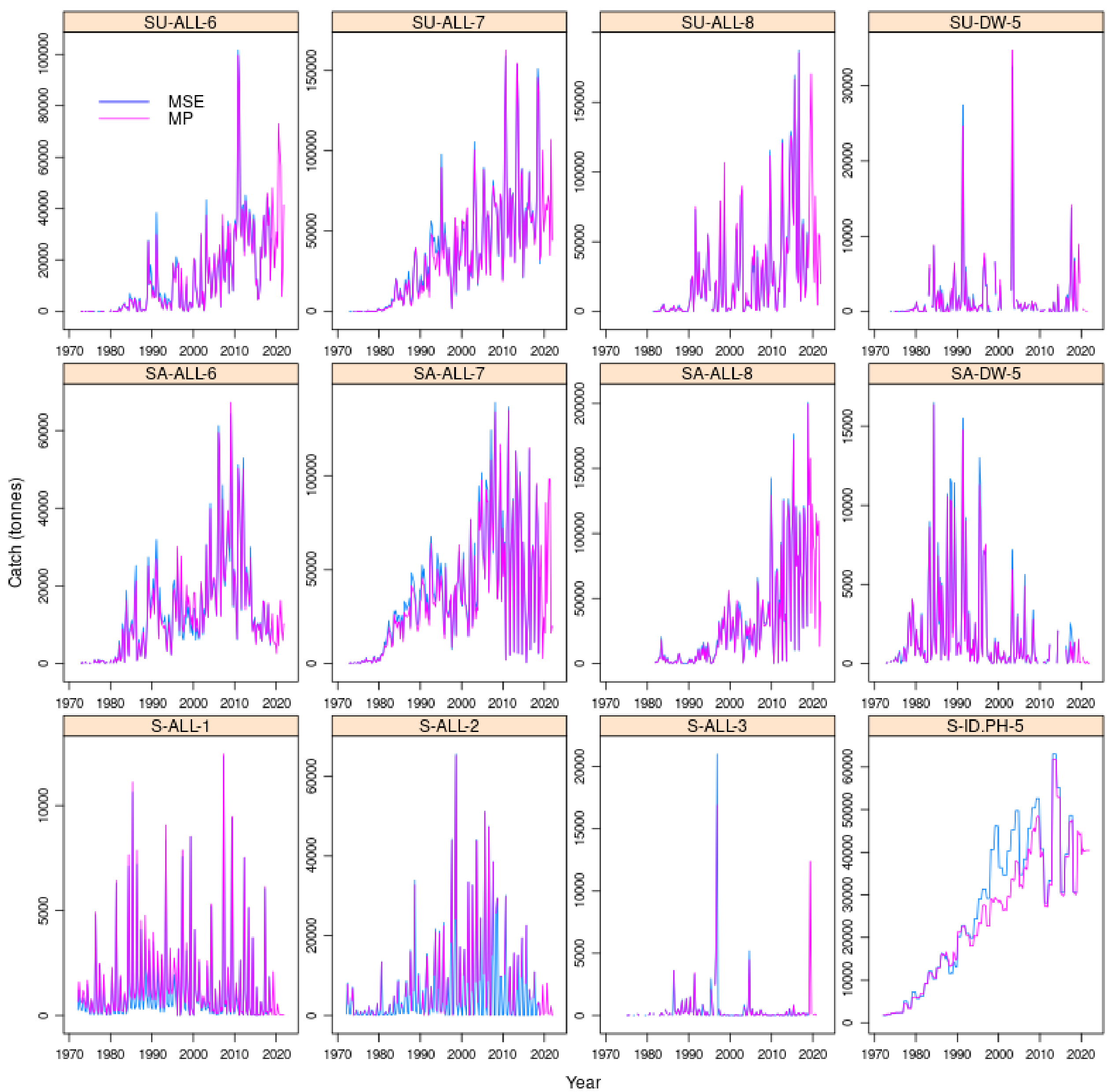

Figure 2: Comparison of historical purse seine catch estimates for the MSE evaluation framework (1972:2018) and the 2022 MP estimation model (1972:2021) inputs.

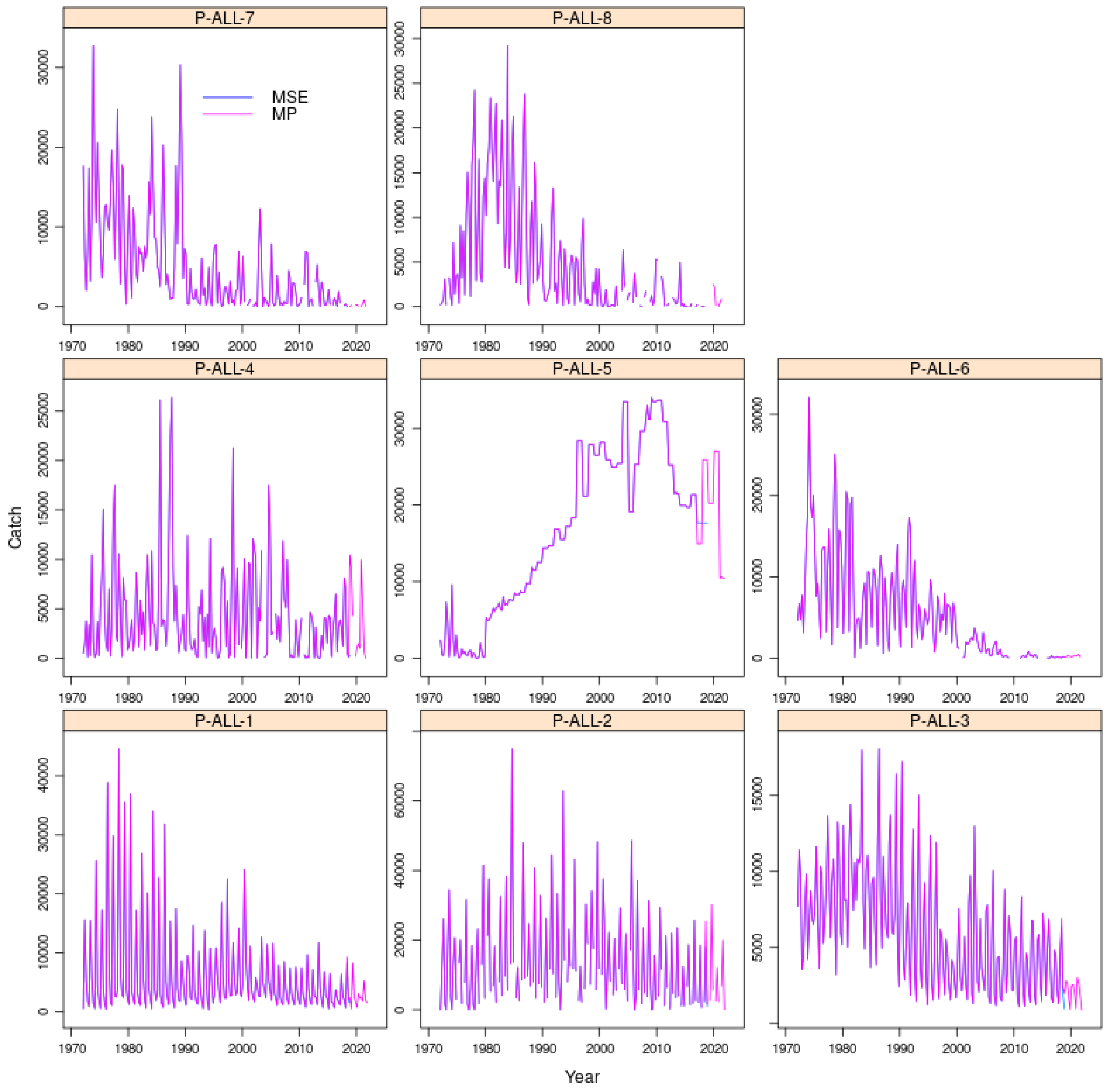

Figure 3: Comparison of historical pole and line catch estimates for the MSE evaluation framework (1972:2018) and the 2022 MP estimation model (1972:2021) inputs.

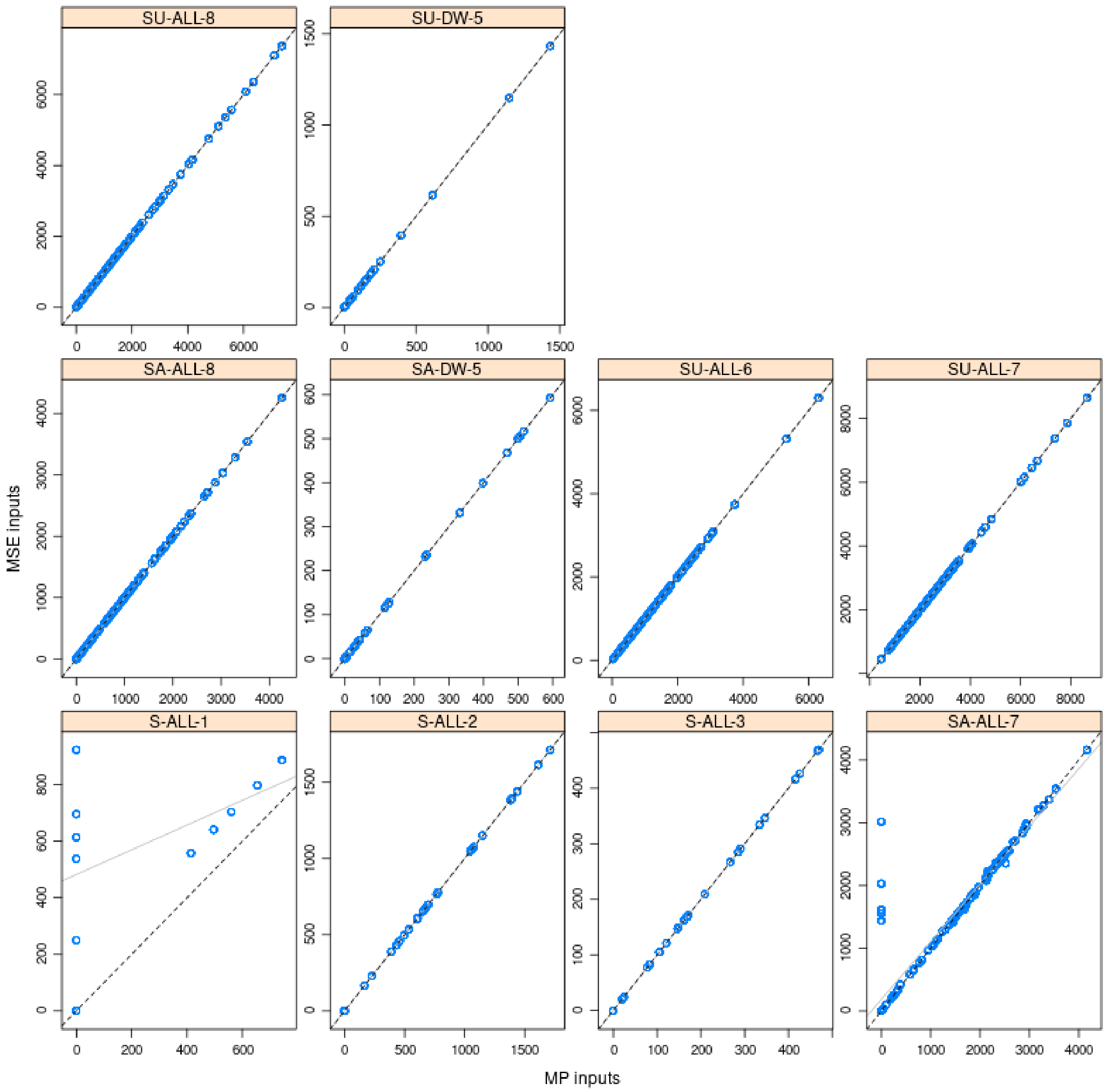

Figure 4: Comparison of historical purse seine effort estimates for the MSE evaluation framework (1972:2018) and the 2022 MP estimation model (1972:2021) inputs.

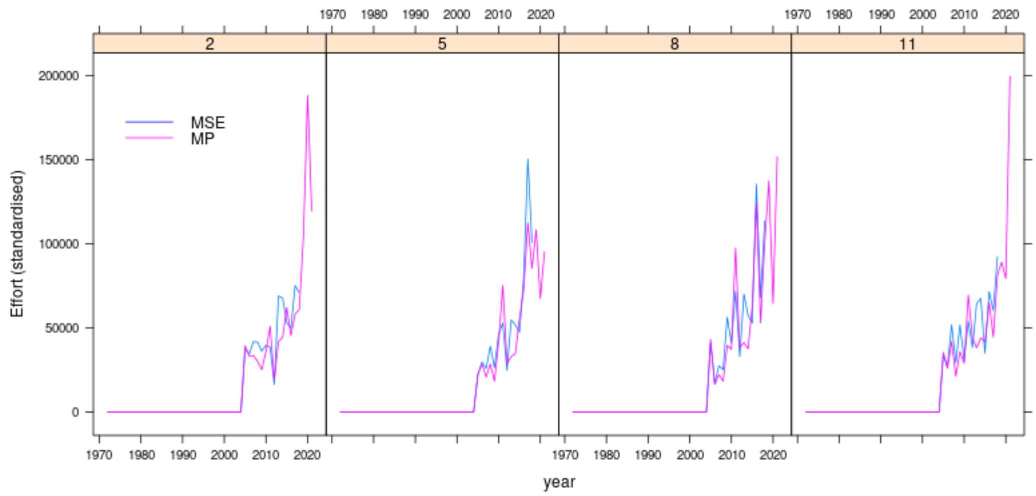

Figure 5: Comparison of quarterly (months 2,5,8,11) purse seine standardised effort for region 5 for the MSE evaluation framework (1972:2018) and the 2022 MP estimation model (1972:2021) inputs.

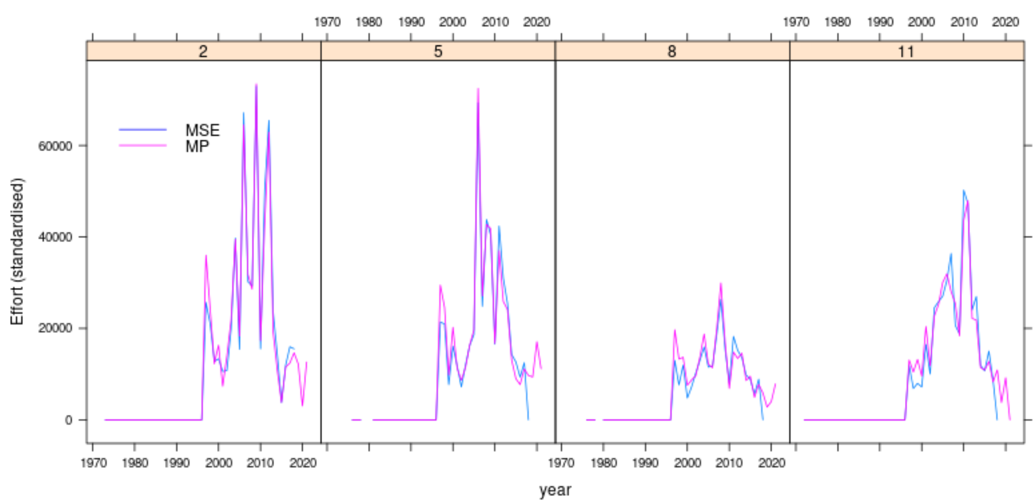

Figure 6: Comparison of quarterly (months 2,5,8,11) purse seine standardised effort for region 6 for the MSE evaluation framework (1972:2018) and the 2022 MP estimation model (1972:2021) inputs.

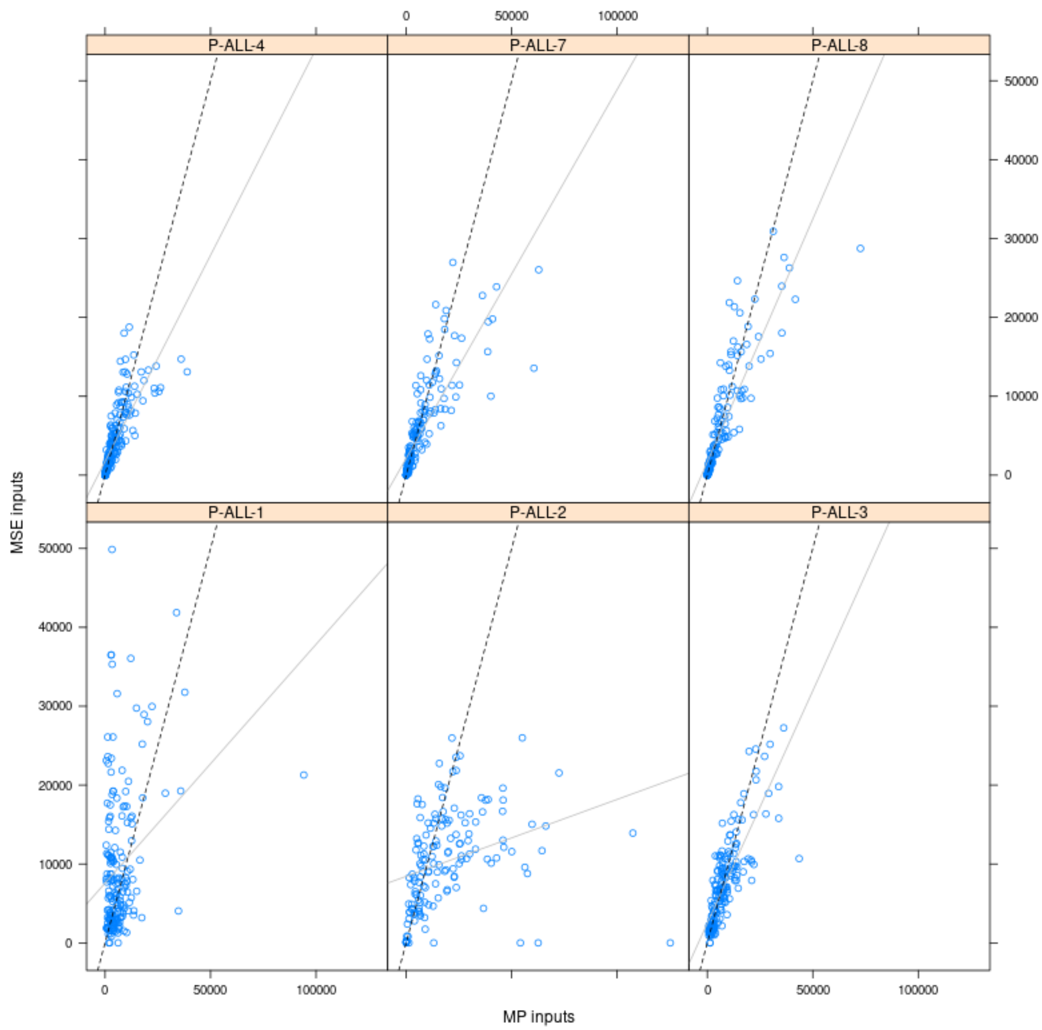

Figure 7: Comparison of standardised effort for pole and line fisheries for the MSE evaluation framework (1972:2018) and the 2022 MP estimation model (1972:2021) inputs.

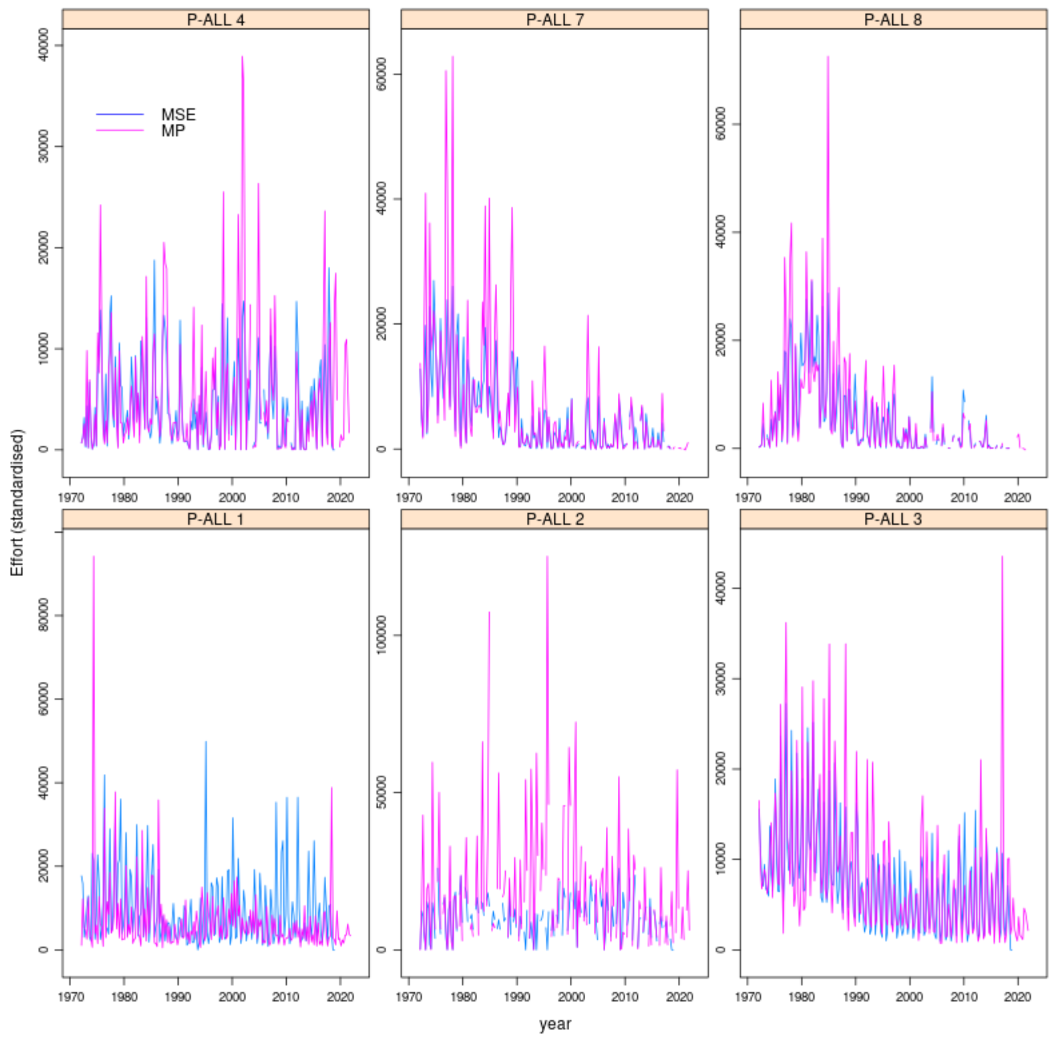

Figure 8: Comparison of standardised effort time series for pole and line fisheries for the MSE evaluation framework (1972:2018) and the 2022 MP estimation model (1972:2021) inputs.

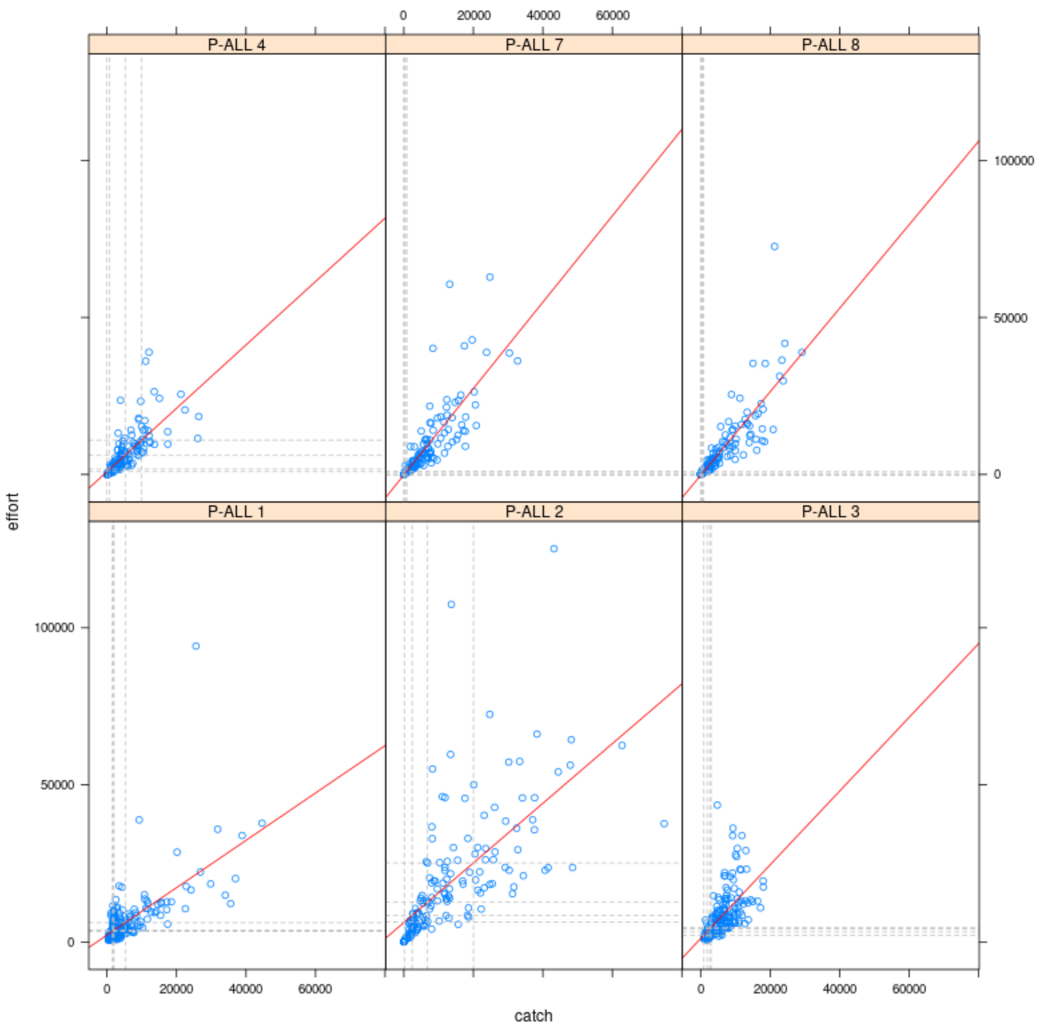

Figure 9: Pole and line catch and effort relationship (red line) used to interpolate 2021 effort levels from available catch information for pole and line fisheries with standardised effort series in regions 1,2,3,4,7 and 8. Dotted grey lines represent 2021 quarterly catches and their corresponding standardised effort values.

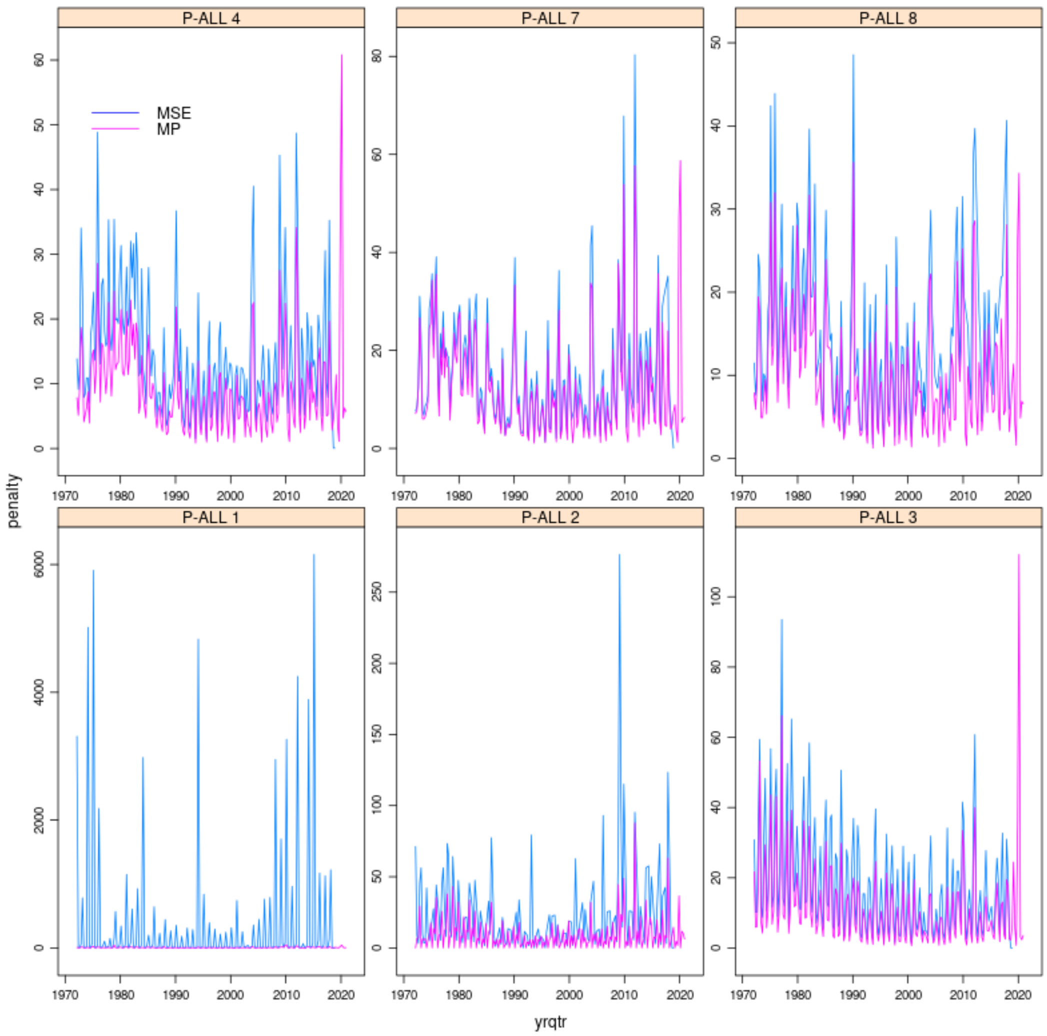

Figure 10: Comparison of time varying penalty terms for pole and line fisheries for the MSE evaluation framework (1972:2018) and the 2022 MP estimation model (1972:2021) inputs.

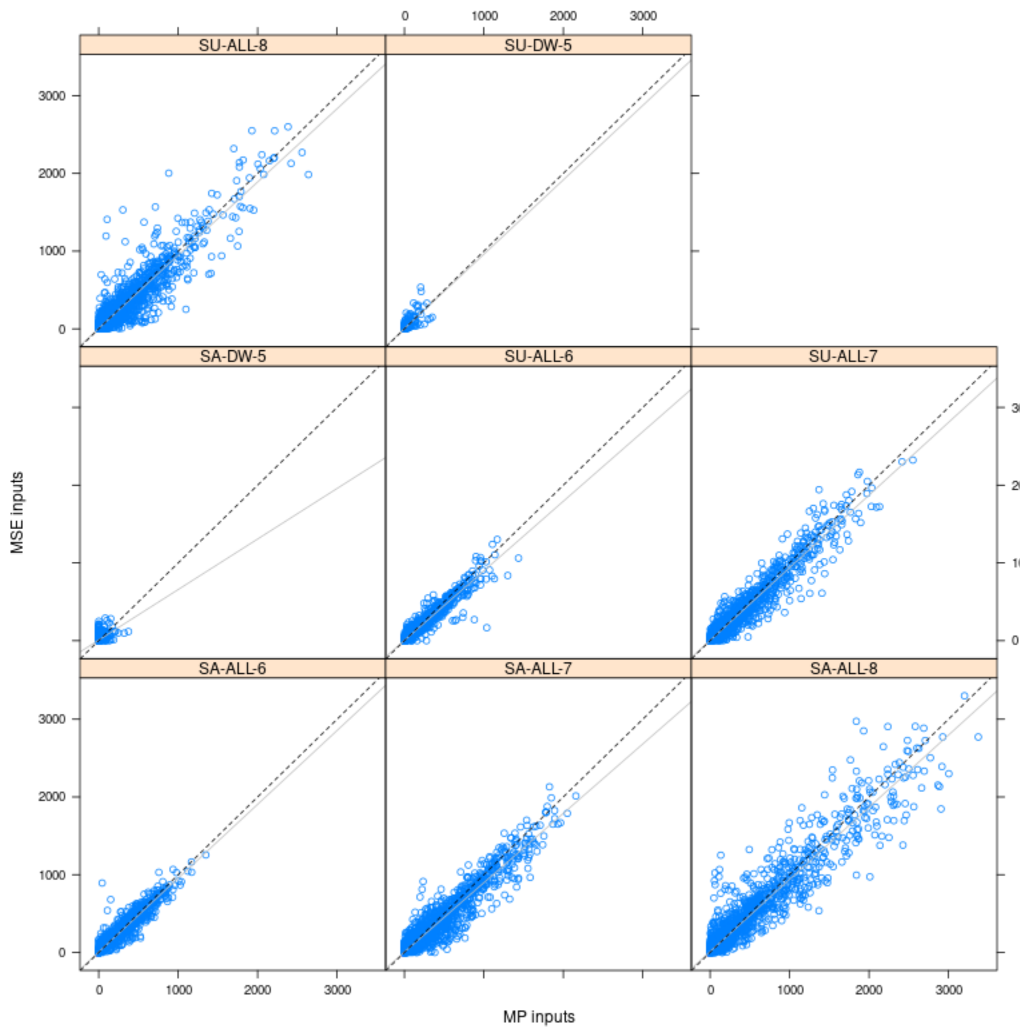

Figure 11: Comparison of purse seine size composition data for the MSE evaluation framework (1972:2018) and the 2022 MP estimation model (1972:2021) inputs.

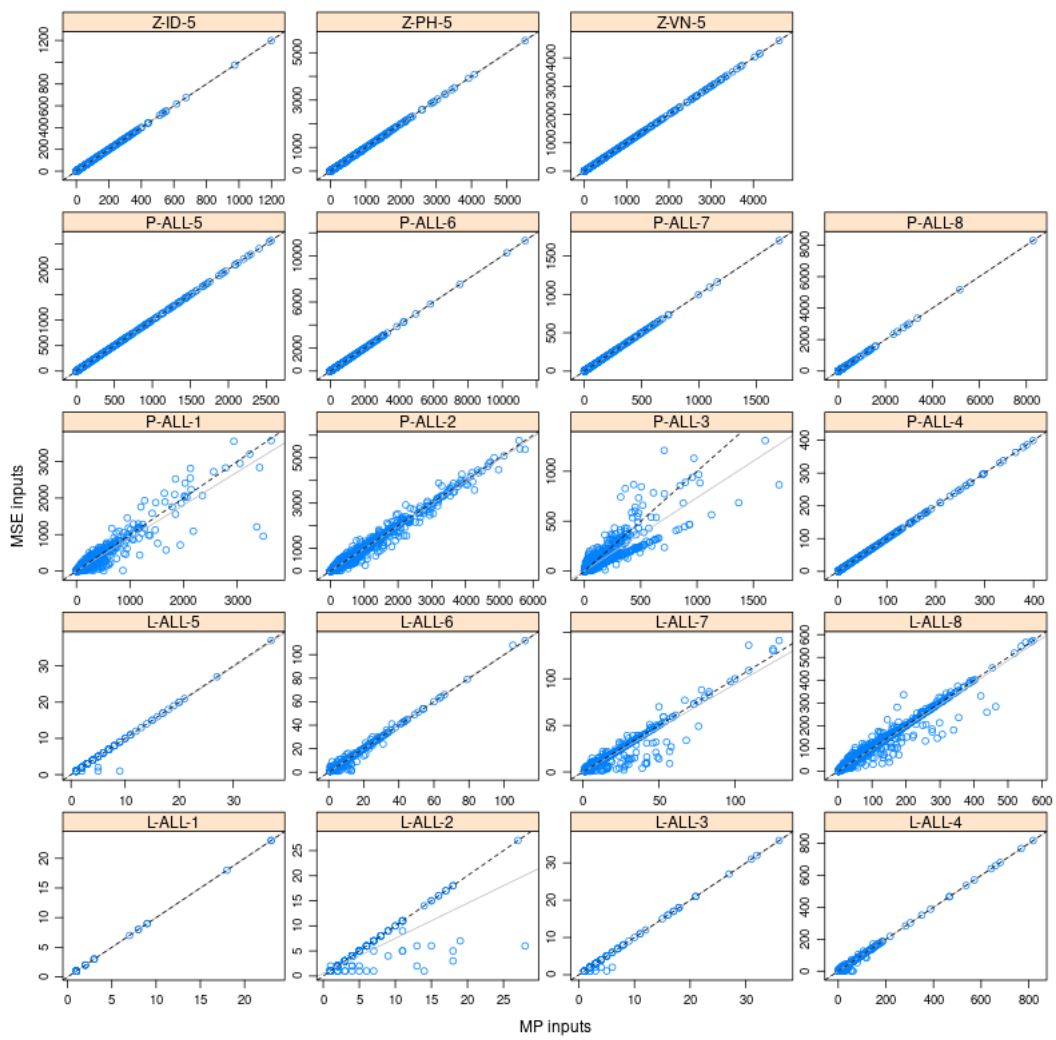

Figure 12: Comparison of size composition data for non-purse seine fisheries for the MSE evaluation framework (1972:2018) and the 2022 MP estimation model (1972:2021) inputs.

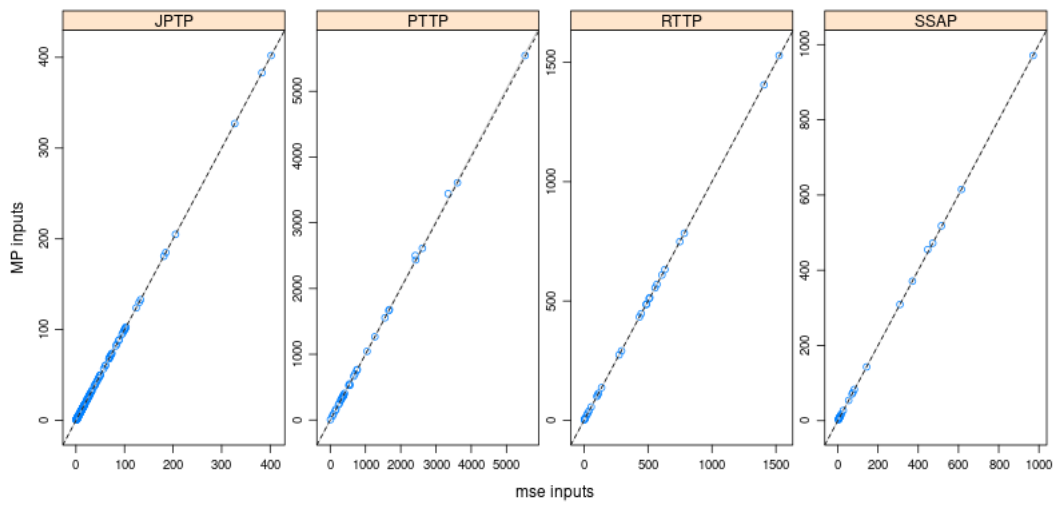

Figure 13: Comparison of historical tag recapture data for the MSE evaluation framework (1972:2018) and the 2022 MP estimation model (1972:2021) inputs.

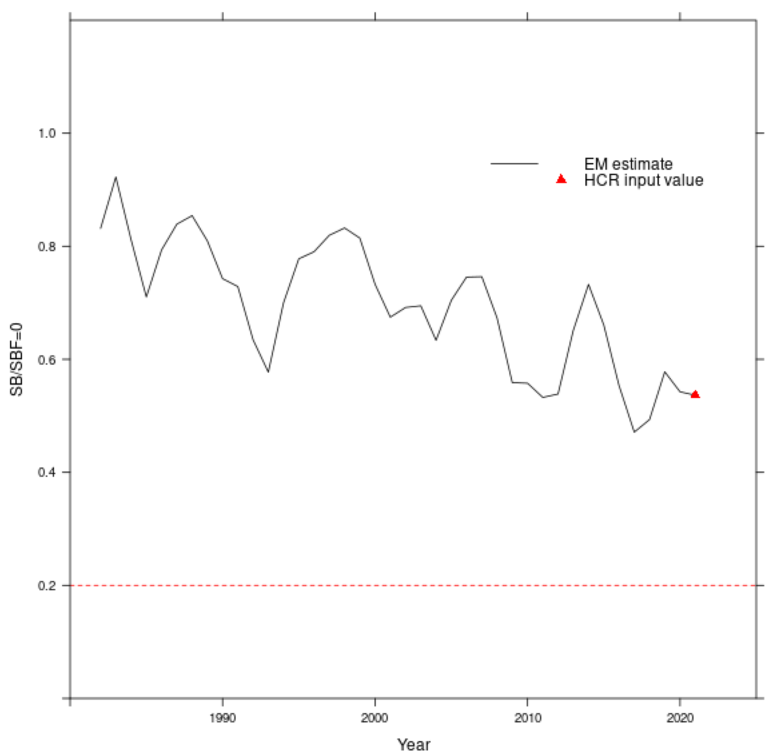

Figure 14: Estimated spawning potential depletion ($SB_{latest}/SB_{F=0}$) as determined from the estimation model (where $SB_{F=0}$ is calculated over a 10 year moving window). The terminal estimate from final estimation phase (shown by the red diamond) is used as the input to the harvest control rule.

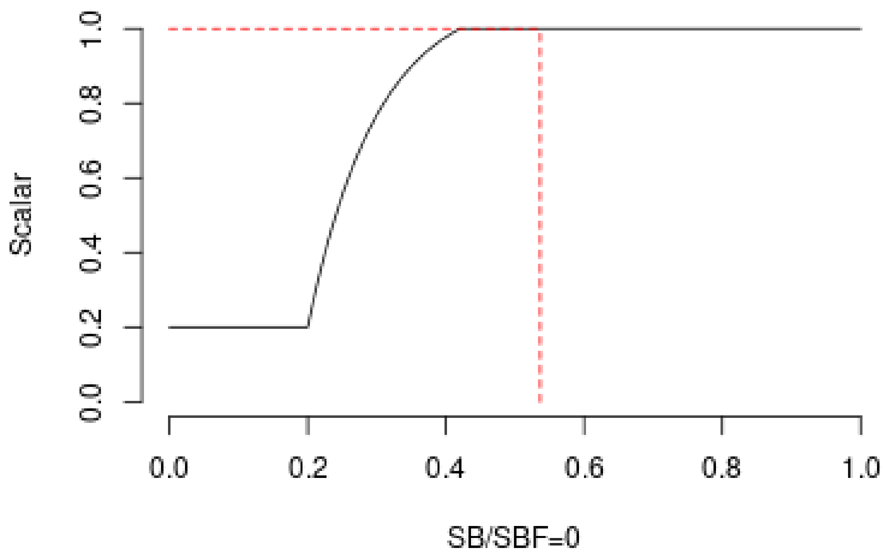

Figure 15: Illustration of the application of a candidate harvest control rule with input based on the estimated spawning potential depletion (SB/SBF=0) in 2021 (0.54) as determined from the estimation model. The output from the HCR is a scalar value of 1 which would set catch and effort in the fishery to 2012 levels.

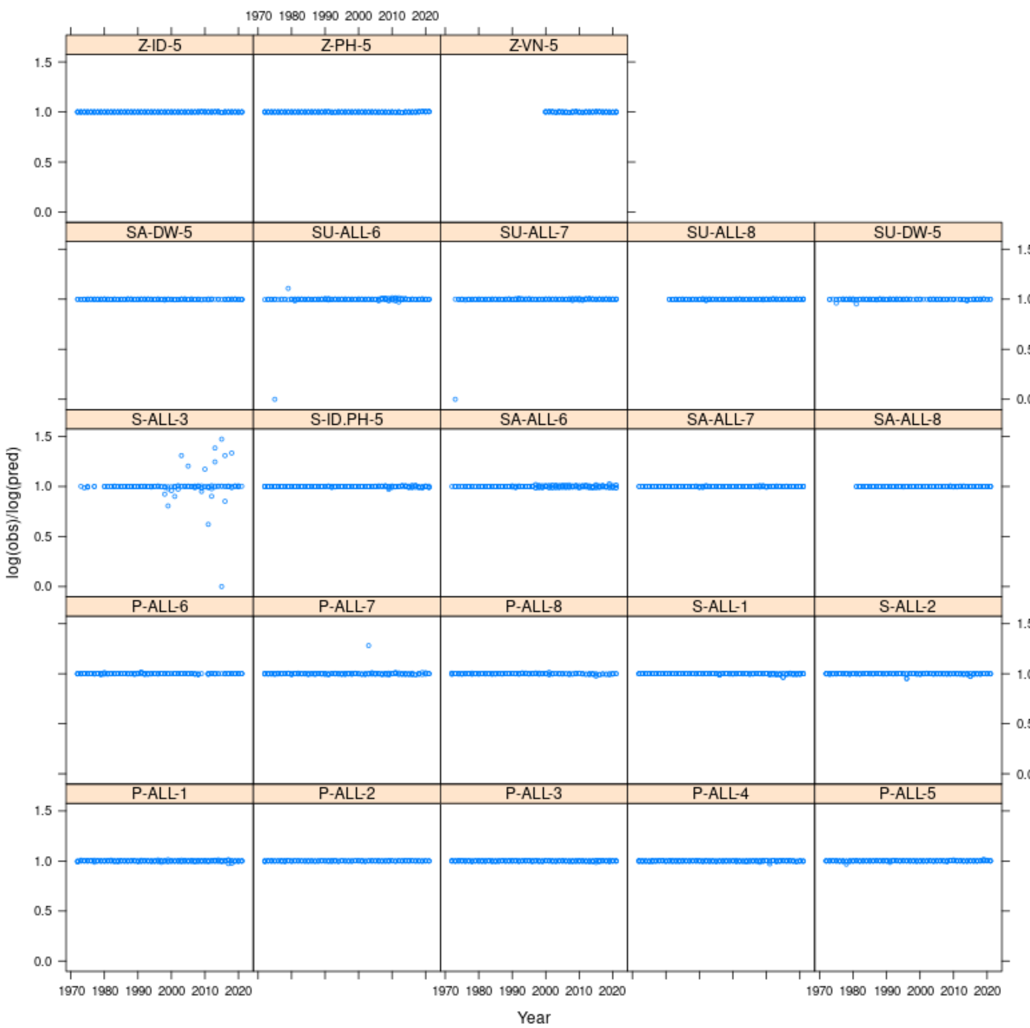

Figure 16: Catch deviations by time period (log(observed)/log(predicted)) from the final phase of the estimation model for all extraction fisheries except longline.

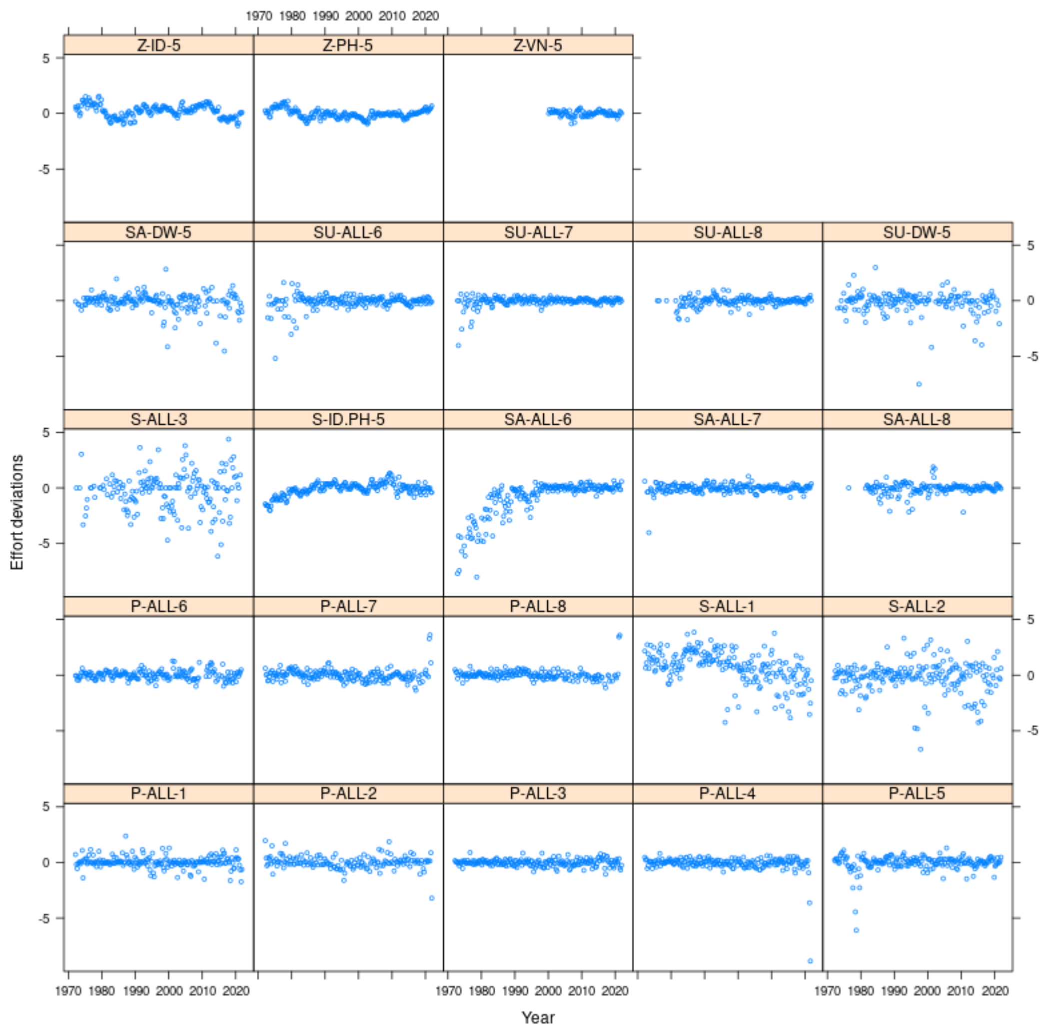

Figure 17: Effort deviations by time period from the final phase of the estimation model for fisheries except longline.

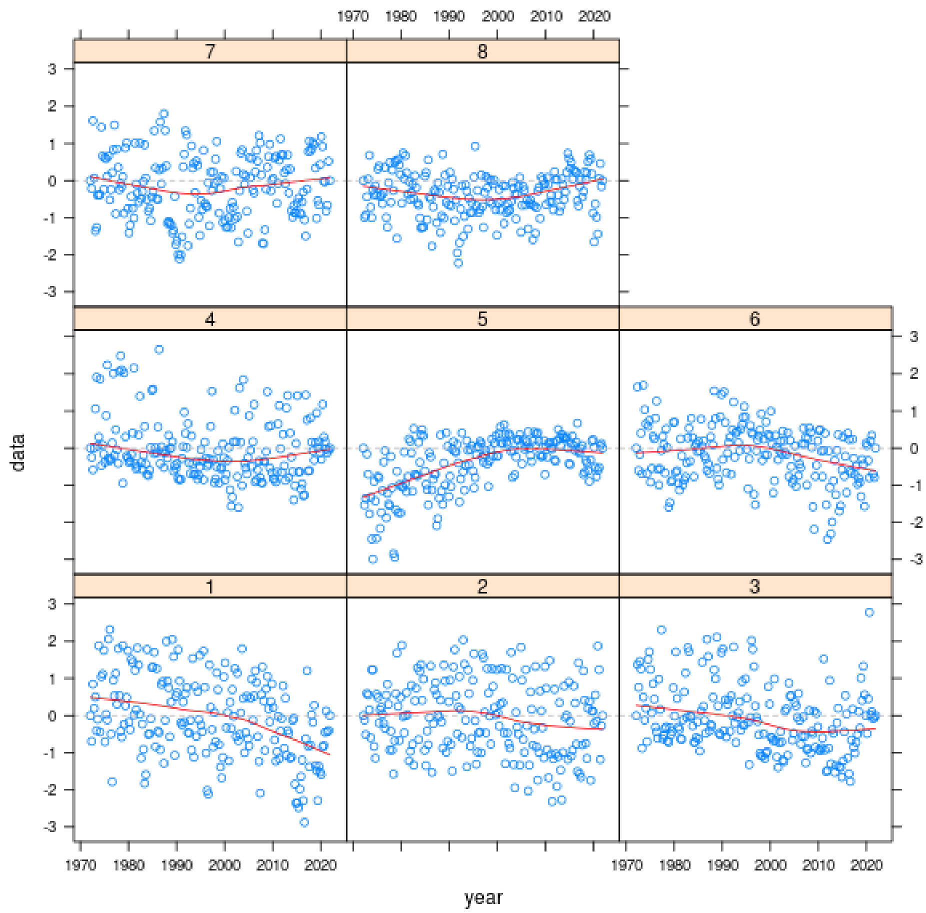

Figure 18: Recruitment deviates by assessment model region. Red line shows a loess smoother fitted to the full time series

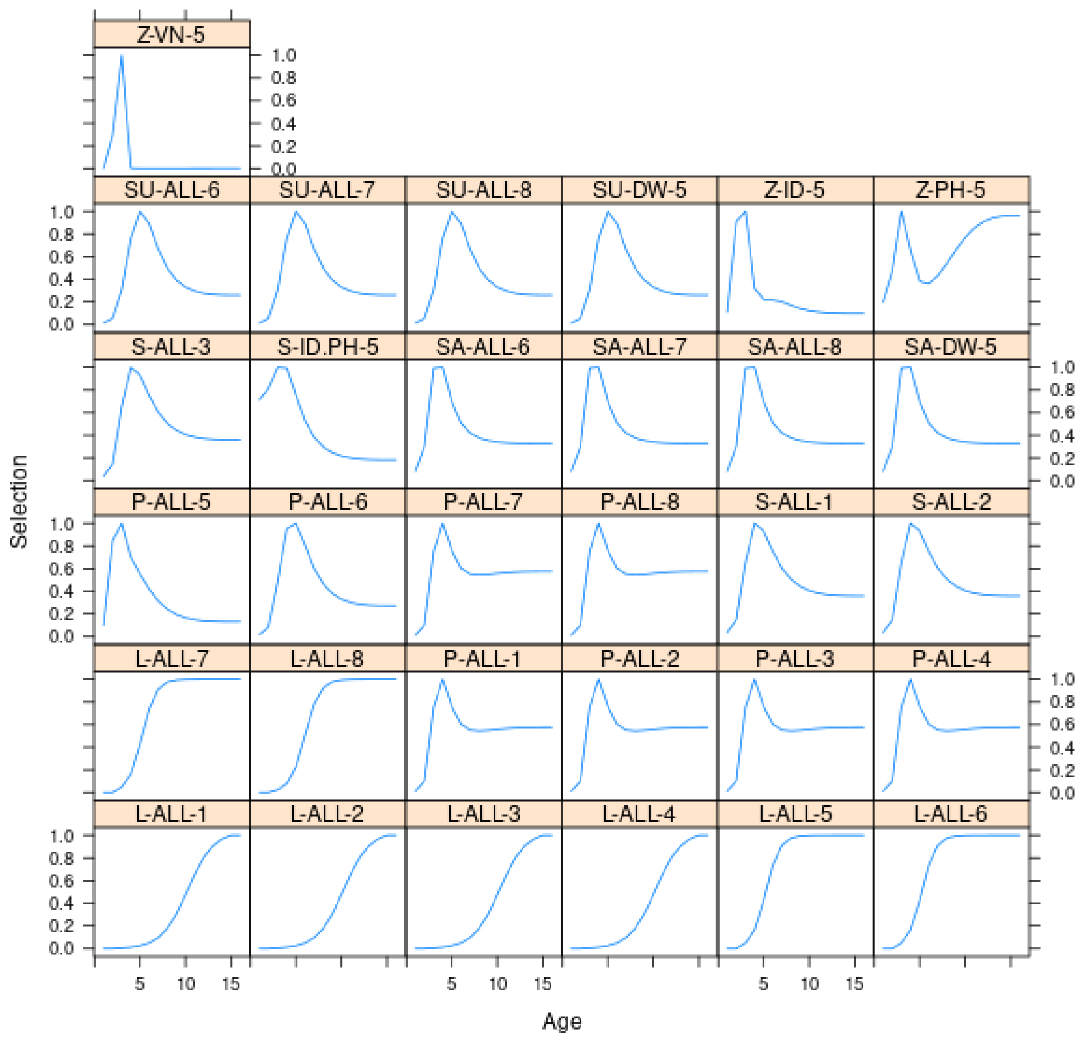

Figure 19: Estimated selection at age by fishery from the final phase of the estimation model.

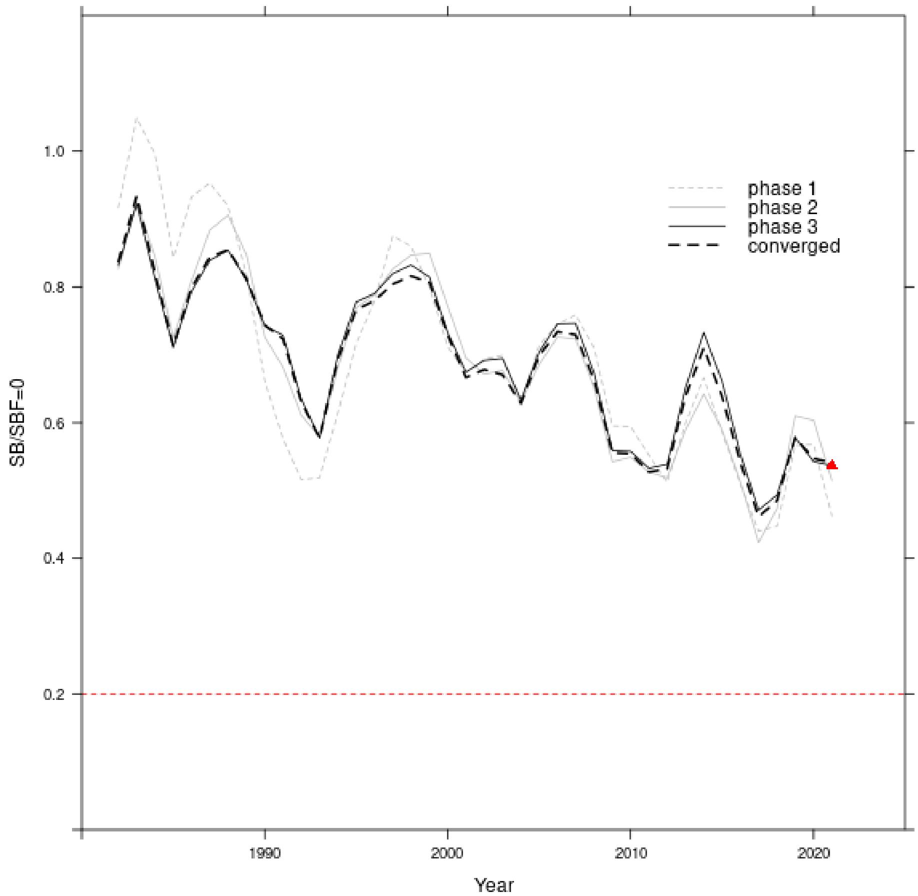

Figure 20: Estimated spawning potential depletion (SB/SBF0 latest) as determined from the estimation model. The model estimates from each of the three phases of the fitting process are shown as well as the results from 4th diagnostic phase in which the model was run to a greater level of convergence. The terminal estimate from final estimation phase (shown by the red diamond) is used as the input to the harvest control rule.

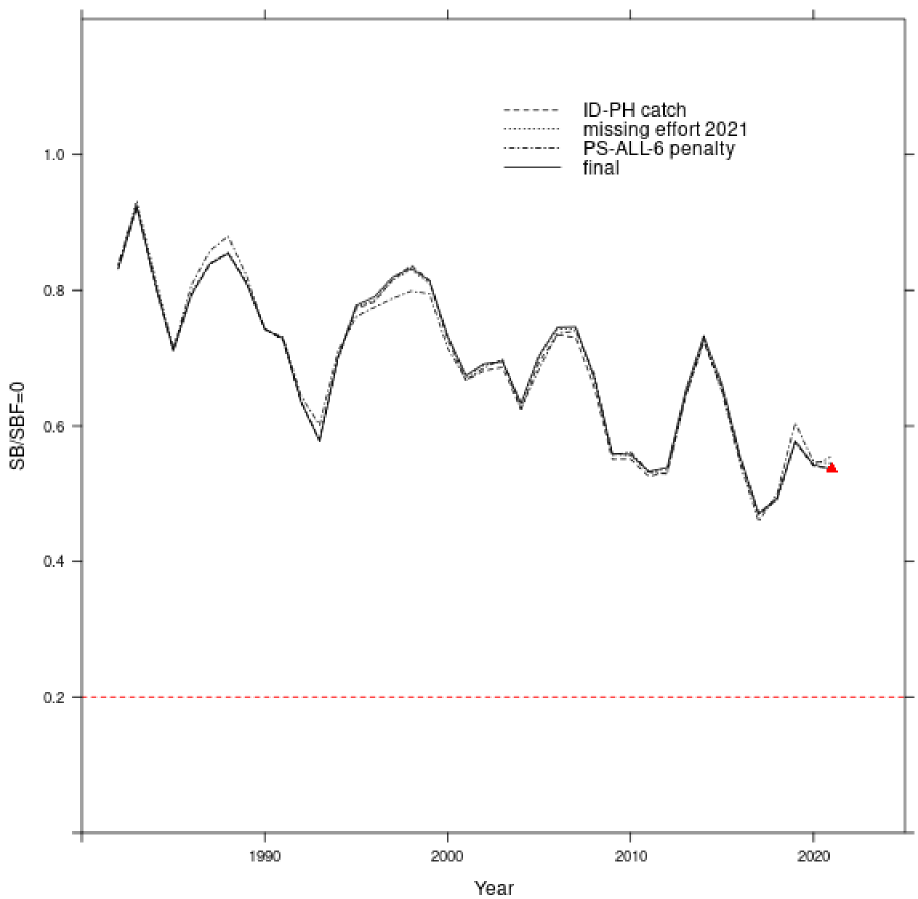

Figure 21: Sensitivity analysis showing estimated spawning potential depletion (SB/SBF0 latest) determined from models with alternative settings for i) ID-PH catch set to 2019 assessment values; ii) Pole and line effort missing in 2021 rather than interpolated; iii) PS-ALL-6 effort penalty terms set to 2019 assessment values. The final estimation model results are shown for comparison.

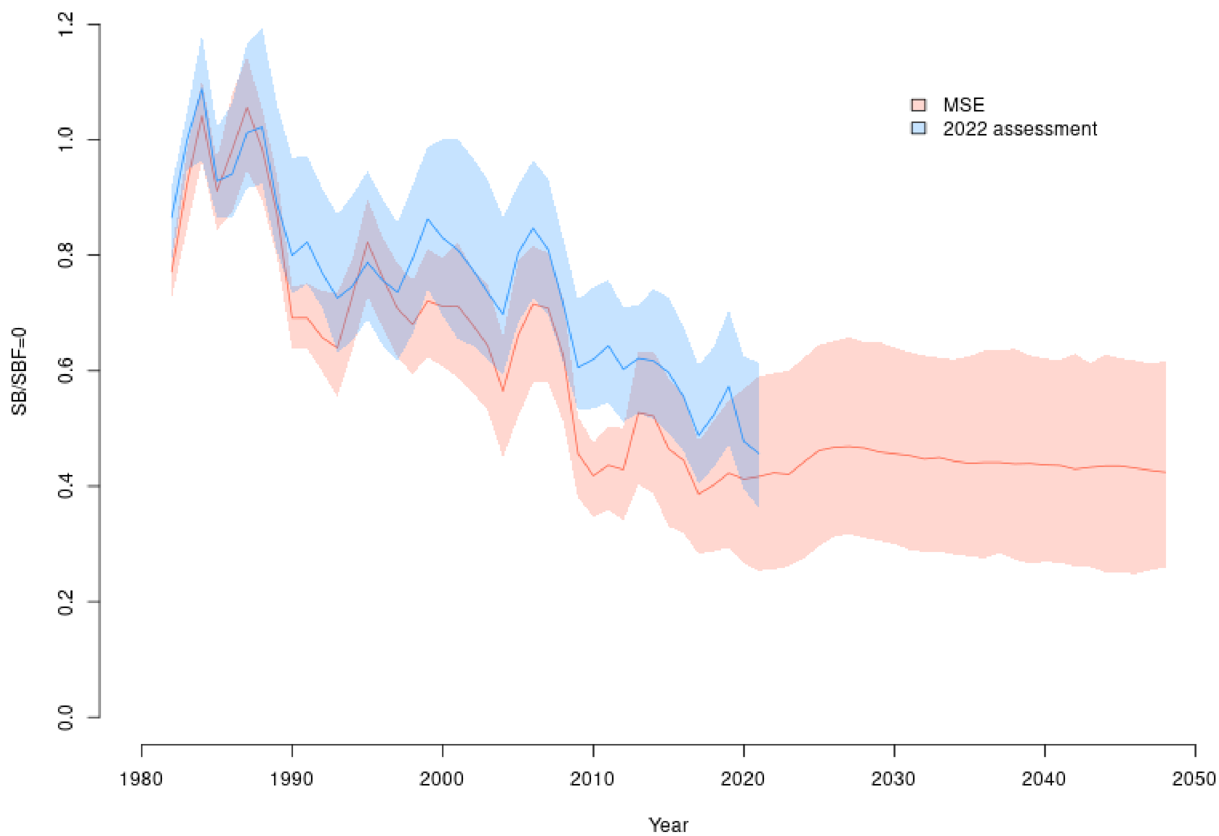

Figure 22: Distribution of predicted spawning potential depletion ($SB_{latest}/SB_{F=0}$) for the MSE evaluations for MP 5 (i.e. the MP that employs HCR 5) and the estimated $SB_{latest}/SB_{F=0}$ from the provisional 2022 stock assessment. The solid red and blue lines represent the median estimate of $SB_{latest}/SB_{F=0}$ for the MSE evaluations and the provisional 2022 assessment respectively.