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Conditioning of operating models and exploratory evaluation of candidate management procedures for SPRFMO jack mackerel

Jack Mackerel Working Group (MSE)

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Iago MOSQUEIRA (WMR) <iago.mosqueira@wur.nl>

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1 Introduction

An important objective in the current Multi-annual workplan of the Scientific Committee (SC) of the South Pacific Regional Fisheries Management Organization (SPRFMO) is the 'MSE development to design alternative harvest control rule'. The objective is for this work to lead to the adoption of a management procedure to replace the current rebuilding plan which is currently used to provide catch advice on Chilean jack mackerel (CJM). The stock is considered to have recovered from the time-series low around 2010, as intended by the rebuilding plan, and is now around the proxy biomass reference levels. Management procedures should thus be explored and evaluated that focus on the long-term exploitation of the stock.

Management Strategy Evaluation (MSE) is considered here as the analysis by which a management procedure is simulation-tested. Simulations are to be carried out on a model that represents our best knowledge of the stock and fisheries past and future dynamics, but also recognizes and quantifies the uncertainties in that knowledge. Operating models are conditioned on the available data and, as it is the case here, are often based on the same population and fishery model used for stock assessment (Sharma et al, 2020).

A management procedure follows three main steps to arrive at a decision to be applied to the fishery:

- An observation and sampling scheme, by which information from the stock (biology and surveys) and the fisheries (catch), is obtained. This process is replicated in MSE by the observation error model (OEM).
- An estimator of stock status or change in it. This could be model-based, for example the JJM stock assessment applied to Chilean jack mackerel, or model-free, based on trends in CPUE series or surveys.
- A Harvest Control Rule, as a function that compares the estimator output with some limits and targets, and provides a value for an output (catch) or input (effort) quantity to be followed by the fishery.

This decision can either be perfectly implemented in the system, or suffer from some level of implementation error, by which discrepancies between advice and the actual application of the management measure can be analysed. Additional processes and dynamics can also be included in MSE, for example technical measures on the fishing gear that alter the fisheries selectivity or catchability.

The results of the simulations of future stock and fishery dynamics under a particular candidate management procedure need to be assessed in comparison with a series of management objectives. A set of performance indicators need to be agreed that best measures how well those multiple objectives are being achieved.

2 MSE framework

The MSE work for SPRFMO jack mackerel is being carried out using the tools developed by the FLR Project (Kell et al. 2007). Development takes place on a source code repository owned by SPRFMO (https://github.com/sprfmo/hcr), to which access can be requested. An R package (FLjjm) has been developed that contains functions specifically written for this study. Many of them use and extend those available already to prepare, run and explore the inputs and output of the JJM stock assessment model through the jjmR package.

Work in the hcr repository is divided into two main section: OM and MSE. The first contains code for the conditioning and evaluation of operating models, while the second includes the code to carry out evaluations of candidate management procedures, and summaries of their performance.

Each of this two sections is set up following the approach designed by the Transparent Assessment Framework (TAF) of the International Council for the Exploration of the Sea (ICES).

3 Stock Assessment

The previous operating model for jack mackerel (Mosqueira and Tien 2022) has been updated to use as its basis the new stock assessment produced by the 2022 benchmark process (SPRFMO 2022a). The stock assessment model runs selected to serve as base case for the OM conditioning process are those also chosen to provide advice on the status of the stock, namely runs 1.02 for both the one stock and two stocks hypothesis.

4 Operating Model conditioning

Operating models are quantitative representations of the past and future dynamics of a stock, or set of stocks, and the fisheries operating on them. Although commonly based on the existing stock assessment model (Sharma et al. 2020), the emphasis is on characterizing the productivity and time series dynamics, together with the uncertainty in their estimation, rather than on obtaining precise values of past and current stock status.

A number of operating models have been developed that attempt to cover a range of important uncertainties previously identified. The OMs are conditioned on the available data using the latest version of the Joint Jack Mackerel model, jjm (SPRFMO 2022b). A number of changes and extensions have been made to the model for its use in the MSE work. They mostly relate to the generation of alternative model outputs or to optimize its performance during simulations, and do not affect the model dynamics.

4.1 Data

Data in the operating model conditioning are the same as used in the latest stock assessment (SPRFMO 2022b) in Annex 8 (model 1.02), namely:

- Catch data (total landings) for the four fisheries.
- Mean weight at age or length by fishery.
- Catch at age for fisheries 1, 2 and 4.
- Catch at length for fishery 3.
- Three CPUE indices from fisheries 2, 3 and 4.
- Three acoustic indices and one DEPM-based index.

Model runs used for conditioning of the operating model used input files available at the SPRFMO github jjm repository, so no specific data preparation took place.

4.2 OM uncertainty grid

A limited number of models assumptions and inputs have concentrated the discussion on structural uncertainty in the operating models. Some of them are part of the standard exploration of uncertainty conducted during the jack mackerel stock assessment work, while others are related to the way the OM is setup for the future. The later can more easily be implemented, as they do not always require the reconditioning of the OM through the JJM model.

Currently, alternative OM formulations are being considered for the following elements:

- Stock-recruit steepness
- Natural mortality
- Growth and weight-at-age
- Effort creep in CPUE fleets

4.3 Parameter uncertainty

For each of the models in the grid, a Markov chain Monte Carlo (McMC) sampling procedure was carried out using the latest version of the no-U-turn (NUTS) sampler for ADMB-based models (Monnahan 2018), as implemented in package adnuts. The sampler was set to run for a total of 12,500 iterations over two chains, with a fifth of those being used as burnin period, and thinning set to one every 10 iterations. A random sample of 500 iterations from each model run was finally used to populate the operating models.

5 Operating Models

The OMs, conditioned using the latest version of the JJM model available in the SPRFMO github jjm repository, were then loaded into classes defined in the FLR mse package. The jack mackerel OMs are built using the *FLombf* class, which contains the following slots to represent each of the elements in the system:

- *biols*, a slot of class *FLBiols* able to contain one or more populations, represented in numbers and biology at age (maturity, mean weight, fecundity), plus a stock-recruitment relationship.
- *fisheries*, a slot of class *FLFisheries* that stores the fishery (effort, capacity) and catch data (landings and discards at age, mean weights, selectivity and catchability) for all fleets operating on the stocks or stocks.
- *refpts*, containing the reference points for each stock to be used when computing MP performance.

Figures 5.1 and 5.2 visualise the first two and last elements in the class, respectively, for the single stock OM.

5.1 Base Case Operating Models

The base case operating models are being employed to carry out initial exploration of candidate MPs, including tuning to a range of potential primary management objectives.

5.1.1 Single stock (h1_1.02)

The single stock base case is built from the current stock assessment run (h1_1.02) with uncertainty computed by the use of McMC, as explained above.

Figure 5.1 presents the main time series (SSB, recruitment and F for the population, and catch per fleet) for the conditioned one-stock OM. Estimates of SSB and F relative to relevant reference points are presented in Figures ?? and ??. The later includes a series of individual trajectories, so as to better present the expected variability of the real population.

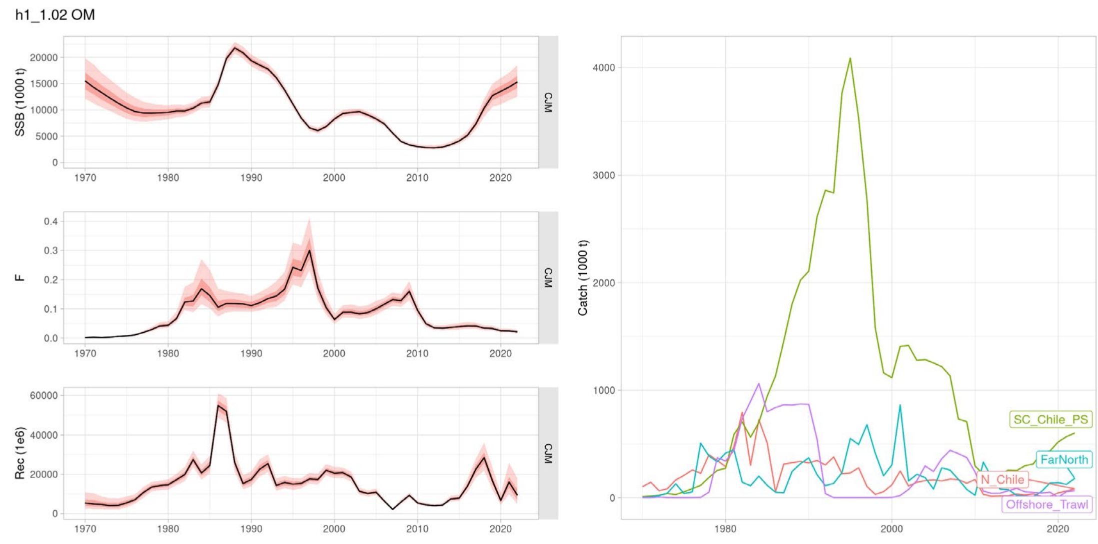

Figure 5.1: Time series of spawning stock biomass (SSB), fishing mortality (F) and recruitment (Rec) (left panel) and catch by fleet (right panel), estimated by the single stock base case operating model (h1_1.02).

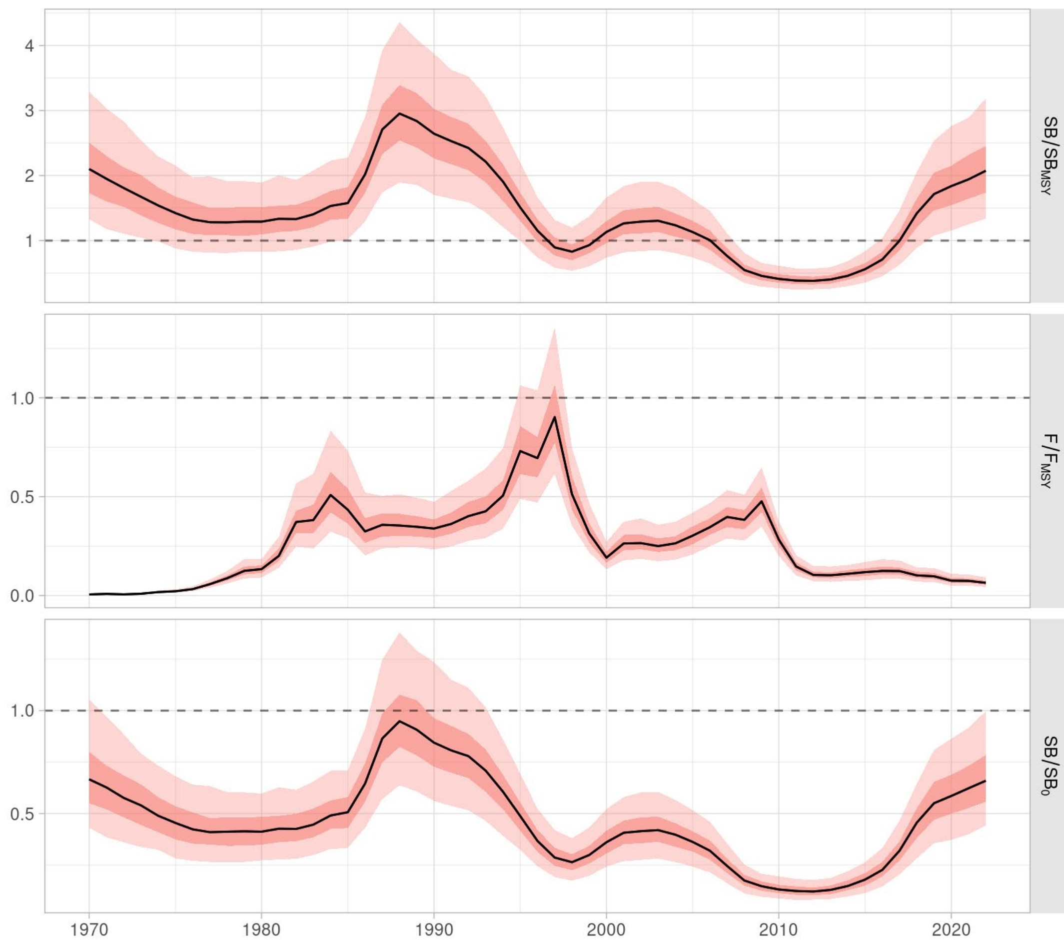

Figure 5.2: Time series of spawning biomass over its most recent MSY reference value, of fishing mortality over the most recent MSY reference levels, and of spanwing biomass over the virgin level on the single stock base case operating model (h1_1.02).

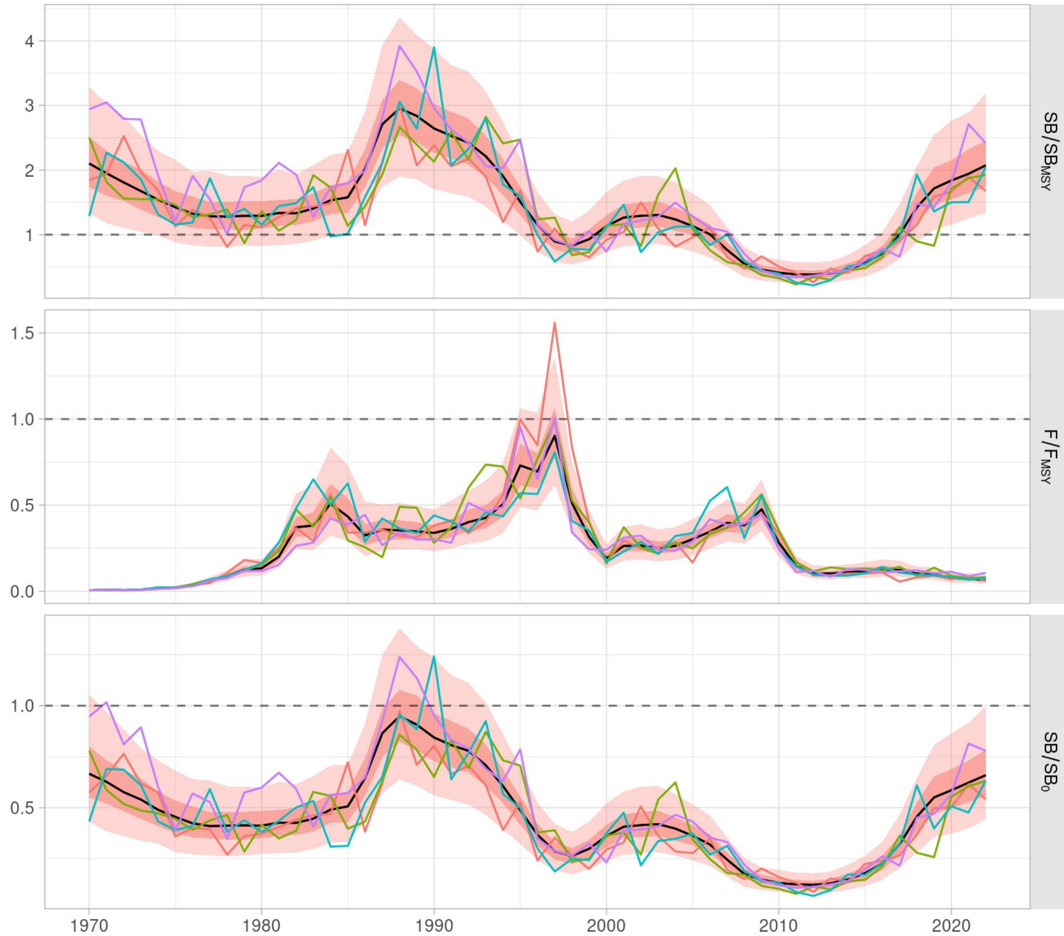

Figure 5.3: Time series of spawning biomass over its most recent MSY reference value, of fishing mortality over the most recent MSY reference levels, and of spanwing biomass over the virgin level on the single stock base case operating model (h1_1.02). A limited number of individual model runs are shown on top to represent the individual variability in trajectories

Parameter uncertainty as quantified by the NUTS McMC sampler also leads to estimates of uncertainty in reference points (Figure 5.4).

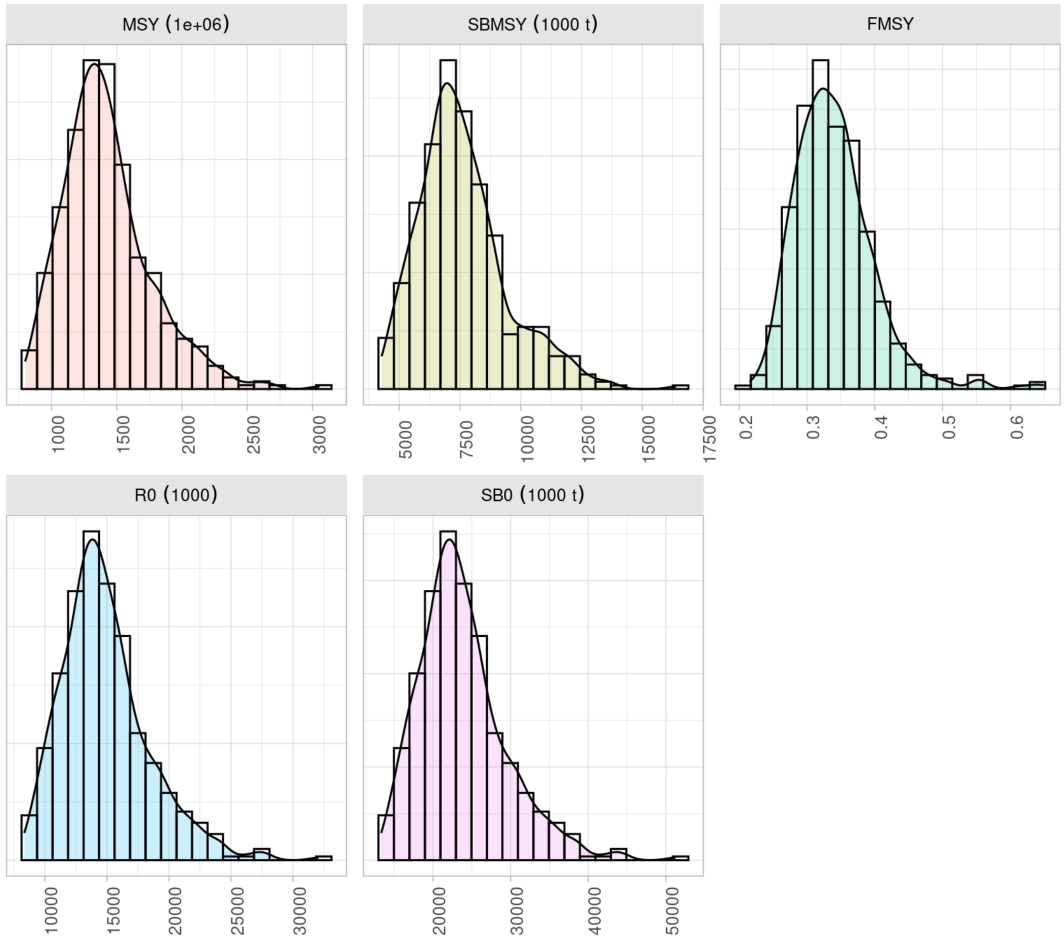

Figure 5.4: Distributions of the estimated reference points for the single stock base case operating model (h1_1.02).

5.1.2 Two stocks (h2_1.02)

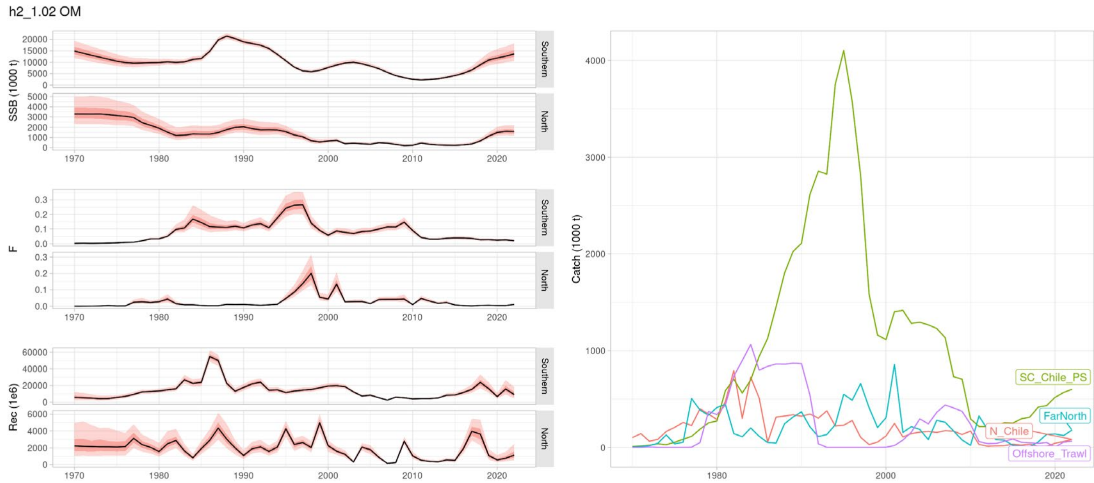

Figure 5.5: Time series of spawning stock biomass (SSB), fishing mortality (F) and recruitment (Rec) (left panel) and catch by fleet (right panel), estimated for the two stocks base case operating model (h2_1.02).

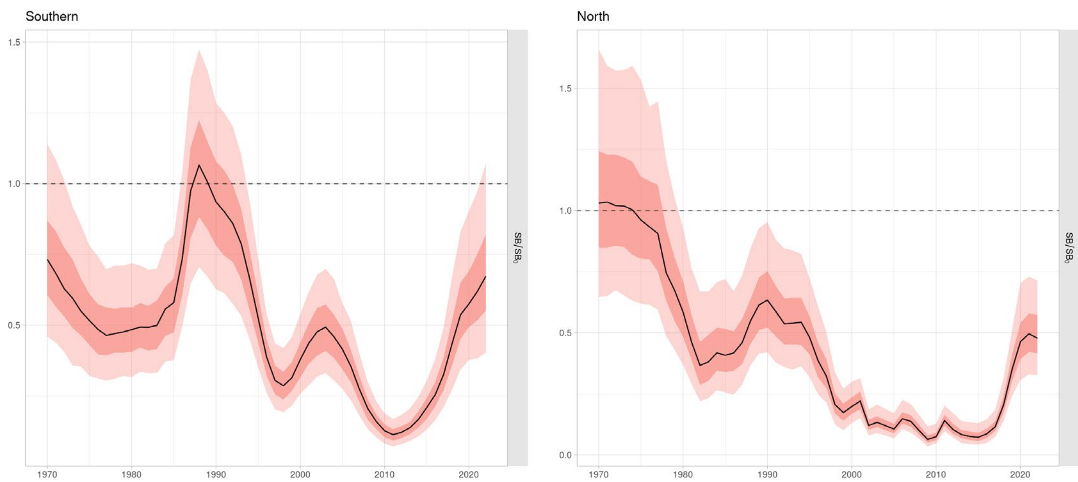

Figure 5.6: Time series of spawning biomass over the virgin level on the two stocks base case operating model (h2_1.02).

5.2 Robustness Operating Models

To be defined, suggested tests include:

- h cycle
- Low recruitment series

5.3 Long term projections

An initial evaluation and comparison of the different operating models cane be carried out by projecting each of them under a set of constant catch and fishing mortality scenarios. For the first, three overall catch levels have been chosen: 750, 1000 and 1250 thousand tonnes, both on the one stock (Figure 5.8) and two stocks (Figure 5.10) OMs. Total catch is split across fleets based on the ratios observed over the last three years.

The constant fishing mortality projections have been carried out assuming no fishing ($F = 0$), F at the most recent level ($F = F_{2022}$), and in the case of the single stock OM (Figure 5.7) also at the MSY level ($F = F_{MSY}$).

Note that some of the constant catch projections (Figures 5.8 and 5.20) reach very large values of fishing mortality, specially for those stock simulations that start at lower biomasses. There is currently almost no limit set in the projections to the increase in effort any fleet is to take for those catch or F levels to be reached. This is an unrealistic assumption that should be revisited based on the possible flexibility and dynamics of the various fleets. Nevertheless, the feedback mechanism of any management procedure should respond to changes in stock abundance before large increases in effort or F are necessary to achieve the projection target.

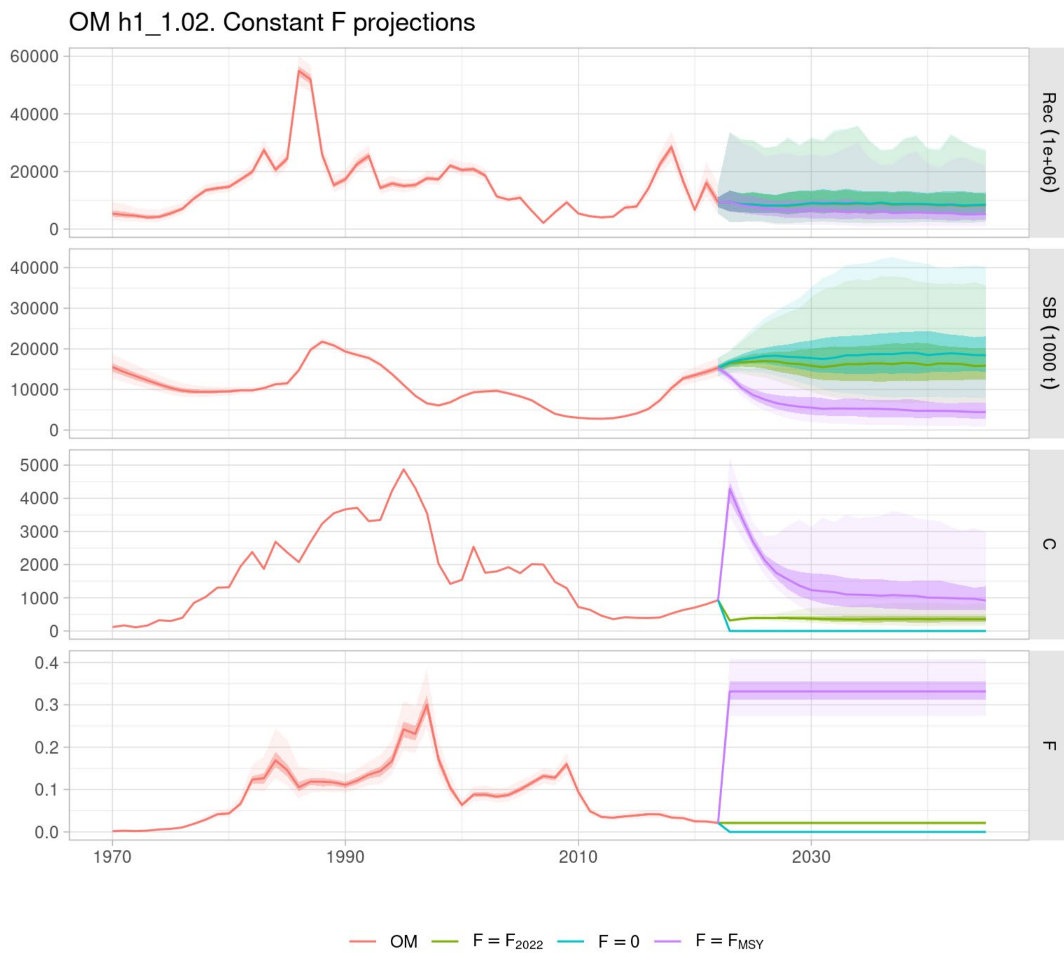

Figure 5.7: Projections for multiple fixed fishing mortality scenarios ($F = 0$, $F = F_{MSY}$ and $F = F_{2022}$) for the single stock OM.

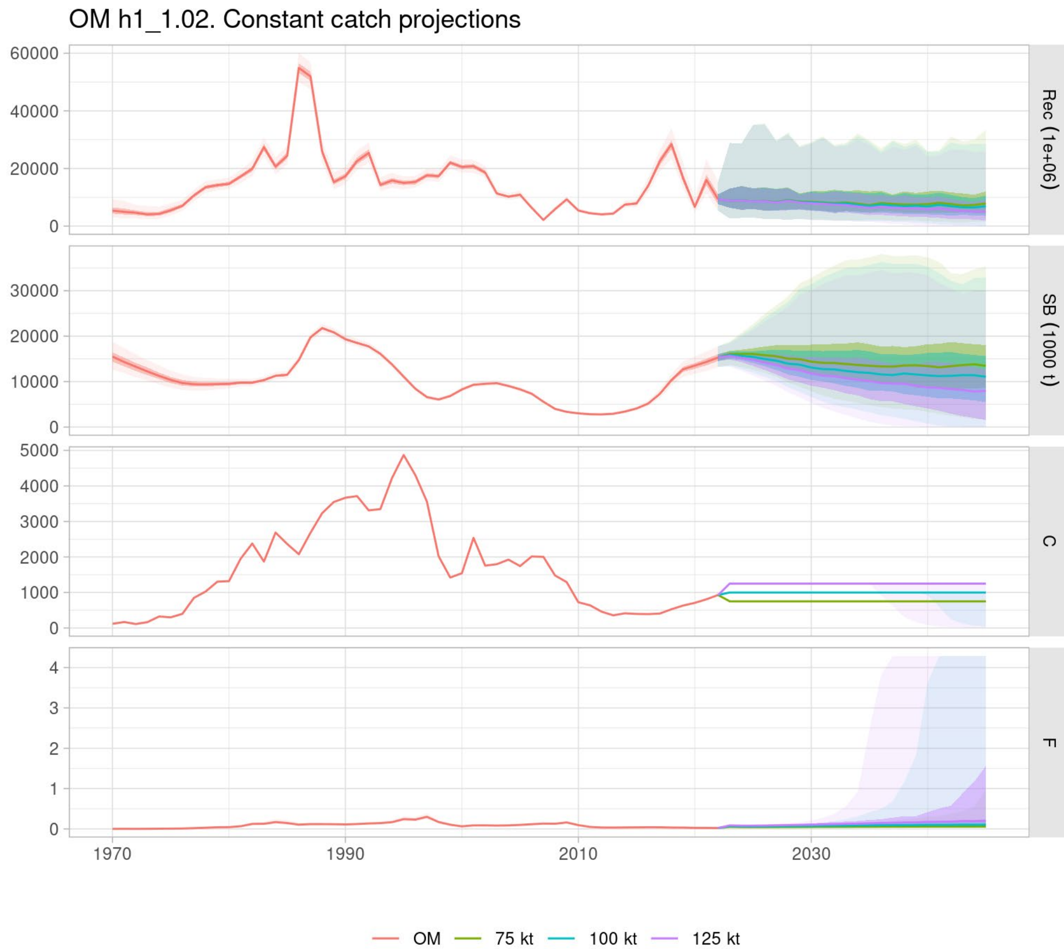

Figure 5.8: Projections for multiple fixed catch level scenarios (7.5e5, 1e6 and 1.25e6 t) for the single stock OM.

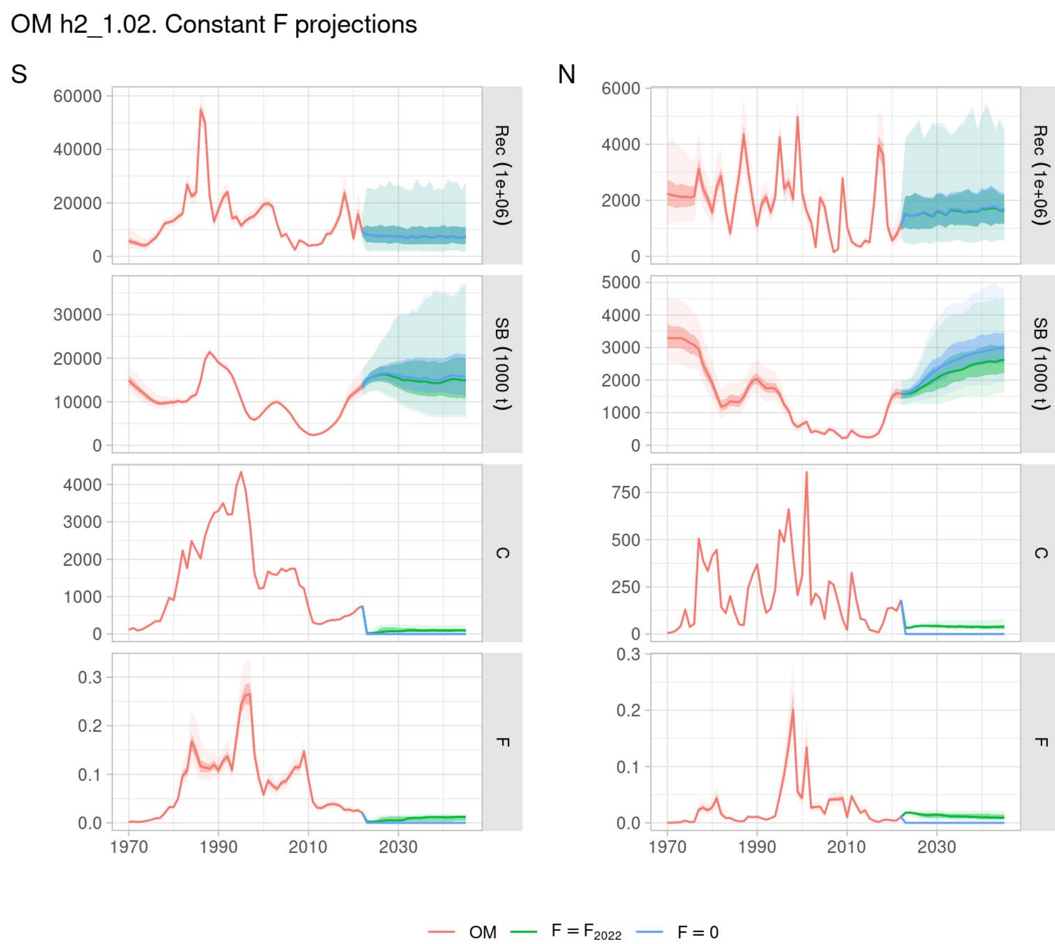

Figure 5.9: Projections for multiple fixed fishing mortality scenarios ($F = 0$, and $F = F_{2022}$) for the two stock (a, Southern and b, North) OM. Fishing mortality here refers to the combined value across both stocks.

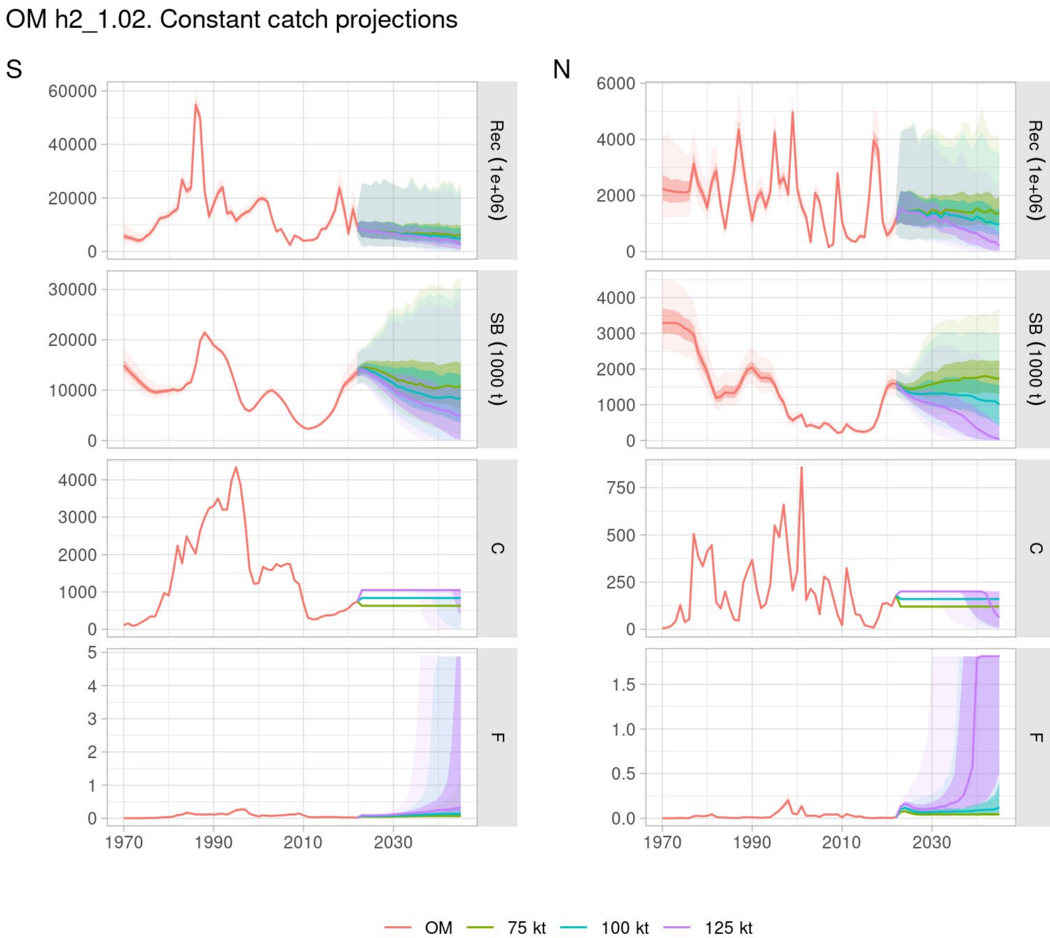

Figure 5.10: Projections for multiple fixed catch level scenarios (7.5e5, 1e6 and 1.25e6 t) for the two stock (a, Southern and b, North) OM. Catch here refers to the combined value across both stocks.

The two-stock OM can also be used to consider the effect of different levels of connectivity in the expected populations dynamics, and on the ability of any MP to succeed under different movement rate scenarios. The conditioning step for the two-stock model does not include any level of connectivity, as there is no data that would allow estimation of rates of exchange, as it is done in some other stocks (Goethel, II, and Cadrin 2011).

Movement between the *North* and *Southern* stocks has been set initially as a transfer of a proportion of the population at each age, at a given point in time every year. This is currently set to be halfway in the year, so as to approximate a constant flow. Information on the seasonality of movement could be incorporated to set a more precise timing. Movement rates are fixed and do not reflect any possible density-dependent process. For each stock, all movement rates are then summed and divided by this sum so that 100% of the fish are accounted for in the movement calculations.

The current movement rates have been assembled from the results of an application of the SEAPODYM ecosystem and population model to the jack mackerel stock (Dragon et al.

2017), and have been presented to the MSE Technical meetings of the Jack Mackerel Working Group. Further discussion and analysis should take place on a range of possible values, and how likely are they to change according to environmental conditions or population size, for example.

The following constant F (Figure 5.11) and catch (Figure 5.12) projections have been carried out incorporating these movement rates.

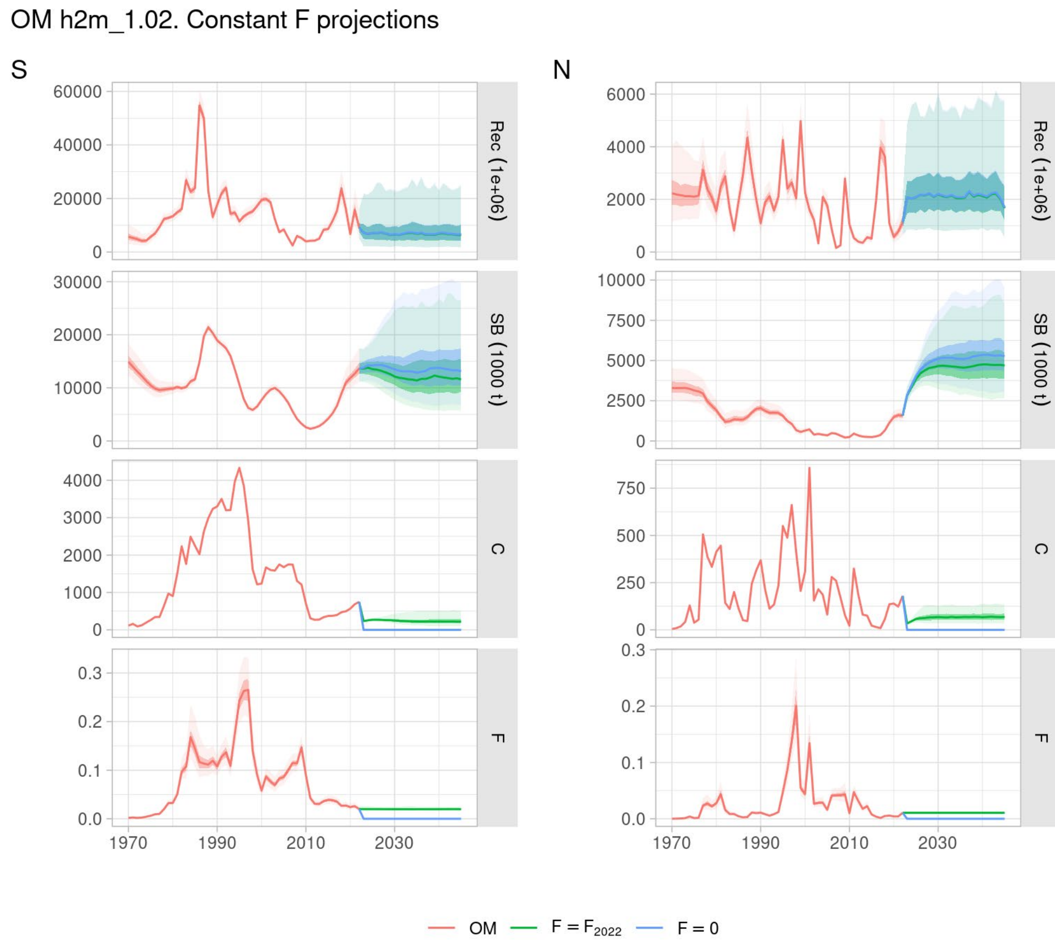

Figure 5.11: Projections for multiple fixed fishing mortality scenarios ($F = 0$, and $F = F_{2022}$) for the two stocks (a, Southern and b, North) OM where movement between them is considered. Fishing mortality here refers to the combined value across both stocks.

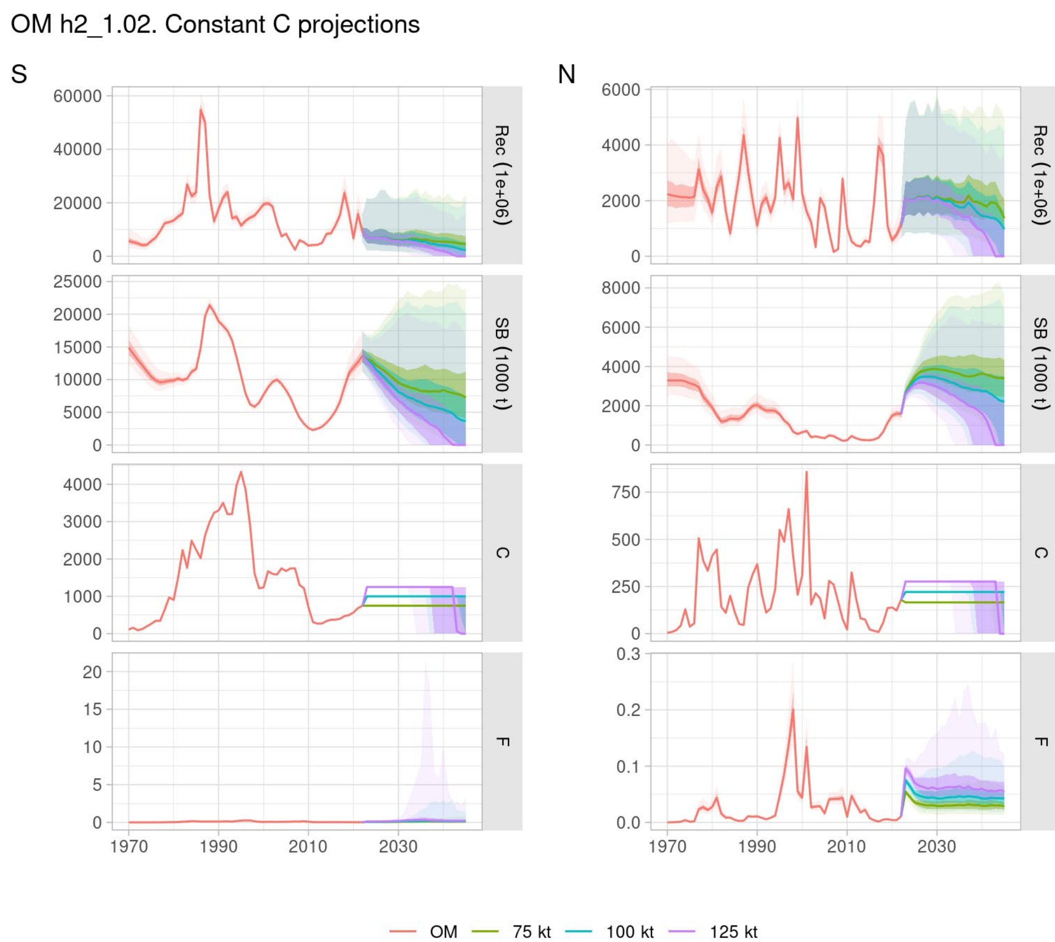

Figure 5.12: Projections for multiple fixed catch level scenarios (7.5e5, 1e6 and 1.25e6 t) for the two stock (a, Southern and b, North) OM where movement between them is considered. Catch here refers to the combined value across both stocks.

A comparison across the stock OMs with (H2M) and without (H2) movement is presented in Figure 5.13 for a single constant catch projection.

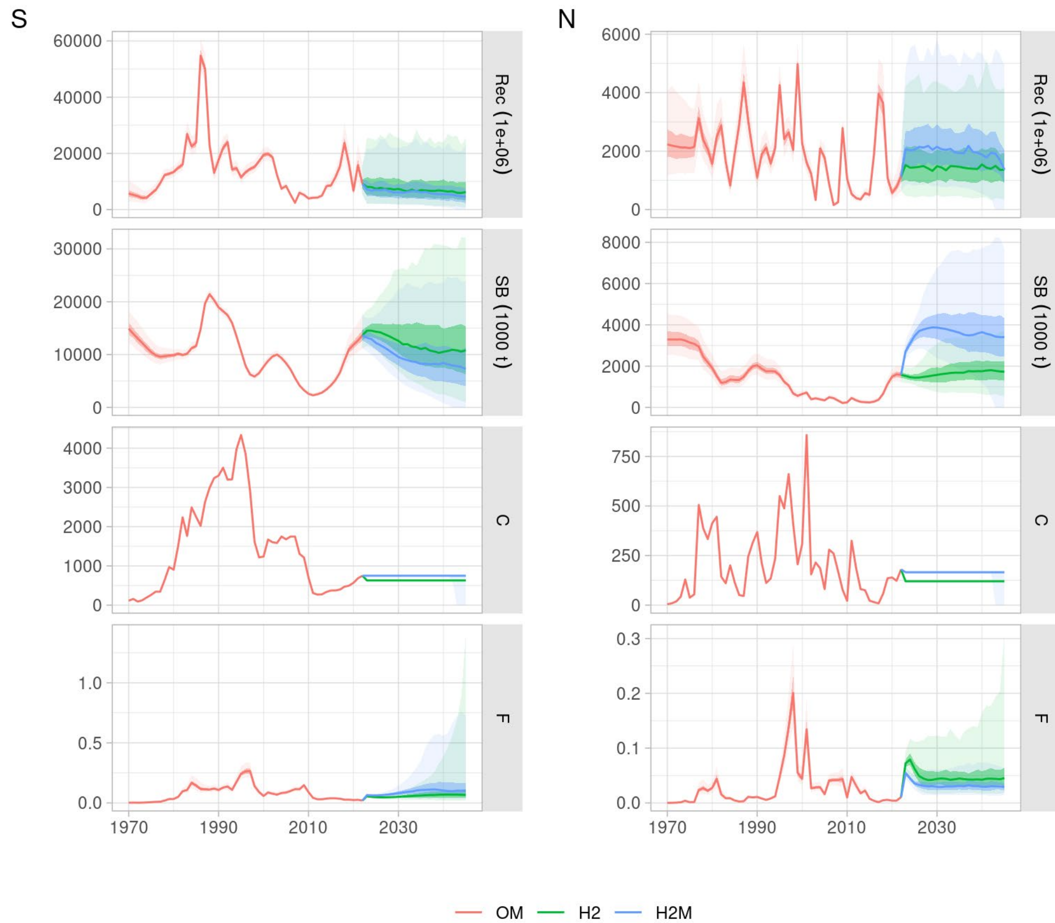

Figure 5.13: Comparison of the projections a single fixed overall catch level (7.5e5 t) for the two stock OM with (H2M, blue) and without (H2, green) movement across stocks. Left panelpresents the Southern stock, while the North one is on the right.

6 Simulation testing

The current simulation specifications for the MSE runs are as follows:

- Simulations start in 2023 and finishes in 2040.
- Data and management lags of 1 year, so each year data is available until the previous year and management is applied the year after. For some individual indices of abundance the data lag is set to two years to reflect the current situation.
- Management frequency of 3 years, so advice is implement for a 3 year period.
- Number of iterations in simulations is set to 500.

6.1 Assumptions

The following elements in the future dynamics of the OMs are being set assuming values informed by those that the conditioning process estimate, unless an alternative scenario has been proposed and quantified. By default future biology (weight-at-age, maturity, …) and fishery processes (selectivity) are set into the future as averages of the estimated or input values over the most recent period (3 years).

6.1.1 Recruitment

Future recruitment is modelled as being determined by a Beverton and Holt stock-recruitment relationship, as fitted in JJM by the conditioning procedure. Deviances over this relationship in future projections, to account for intrinsic and extrinsic variability, have been set as following a lognormal probability distribution, with variance and lag one autocorrelation as computed from the deviances returned by the OM conditioning McMC procedure.

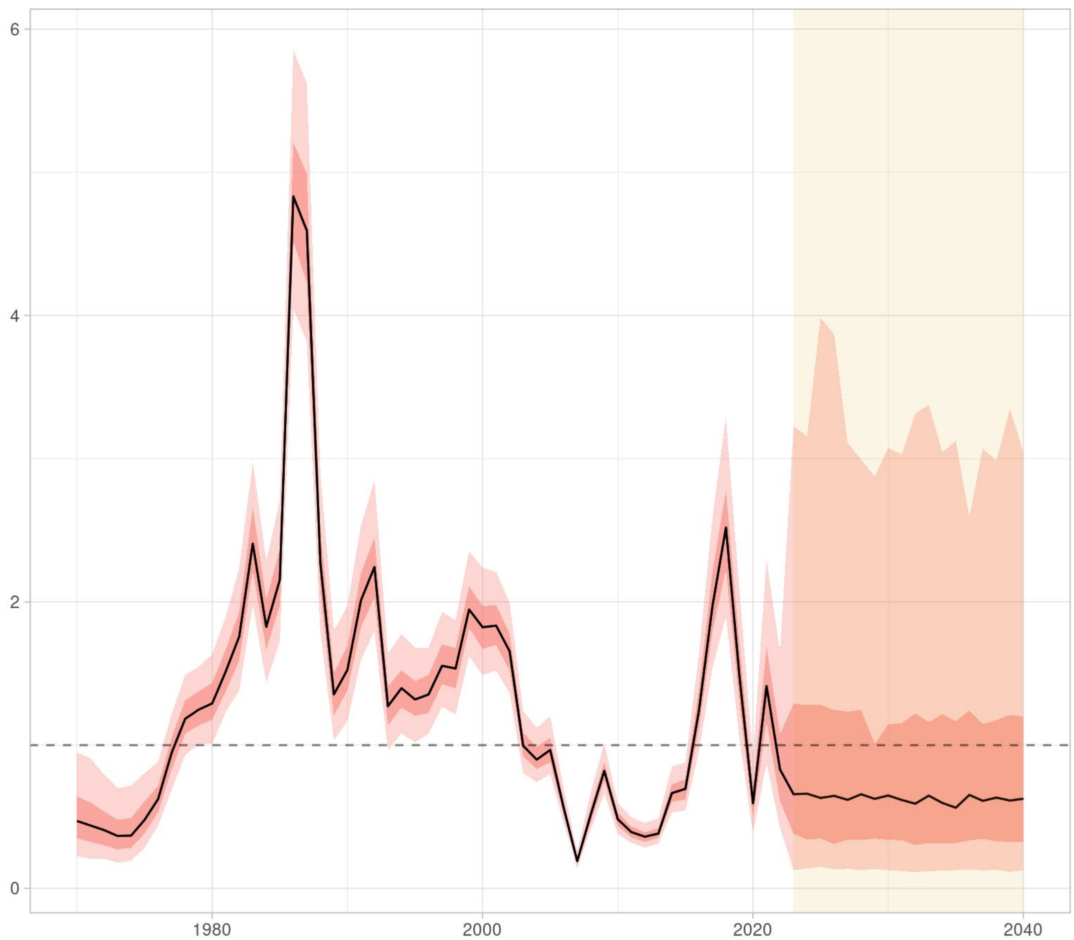

Figure 6.1: Time series of stock-recruitment deviances in the conditioned one-stock OM (h1). Future deviances are highlighted by the shaded area.

Robustness tests will include alternative recruitment dynamics, to assess, for example, the robustness of the MPs to a series of low recruitments caused by environmental conditions. No environmental drivers have been identified at the moment that could be used to determine future changes in recruitment dynamics.

6.1.2 Implementation error

At the present moment, no implementation error is being considered in the simulations. The decision provided as maximum catch advice is fully taken, unless limits in abundance or effort make it impossible.

6.2 Generation of Future Data

6.2.1 Indices of abundance

A proposal has been made to consider different levels of effort or efficiency creep in some of the fleets used to generate indices of abundance. CPUE series assume that the relationship between changes in effort and catch is stable (Gulland 1983), or that changes due to an increase in efficiency, or any other operational factors, are accounted for by some standardization procedure (Maunder and Punt 2004). The updated JJM model (SPRFMO 2022b) incorporates indices corrected for the increase in efficiency, estimated at approximately 2.5% for the offshore CPUE and 1% for the Chilean and Peruvian CPUE indices. A test run of the base case stock assessment was carried out with lower (0%) and higher (2.5% across all indices) correction levels. The effect on stock dynamics appears to be limited.

Potential future increases in CPUE efficiency could be incorporated by changes in time in the α parameter of the fishing mortality to effort relationship used to project fisheries into the future. In this way the catch levels obtained by a fleet, and also the signal its CPUE provides on changes in stock abundance, will be affected by those changes. Observations for the various indices of abundance are generated under an assumed value for the constant of proportionality that relates them to stock level. This constant, estimated during the conditioning process, could also be made to change in time for certain fleets that are changing in area or other operational factor.

Observation error across the different abundance indices is currently being set to follow a lognormal distribution, with variance determined for each of them from the residuals of the OM conditioning fits.

6.2.2 Catches

Observation error on the catch-at-age and catch-at-length datasets is currently being set to follow a lognormal distribution with a fixed variance (0.2 in log scale), equal for all fleets.

7 Candidate Management Procedures

Management procedures (MPs), also termed management or harvest strategies (Rademeyer, Plagányi, and Butterworth 2007), consist of a number of processes and calculations that link observations and data from the fisheries system, to an implementable decision on the activity of the fishery. The following steps are being included in the current simulation setup:

- Data collection
- Status estimation
- Decision rule
- Implementation system
- Implementation error

Three alternative types of MP have been implemented for the SPRFMO jack mackerel fishery and are being explored and evaluated. Two of them are intended to generate candidate MPs for potential improvement and adoption. The first is based on the current stock assessment model for the stock, the Joint Jack Mackerel model (SPRFMO 2022b). The second one is a model-free MP, in which changes in stock status are determined by a relative exploitation rate, as computed from total catch and an index of abundance (Fischer et al. 2022). The third MP substitutes the stock assessment with a *shortcut* by means of a direct observation of abundance with some set error level on the observed metric, in this case SSB. This method allows development and demonstration of the MSE platform without incurring the high computational costs of fitting the full stock assessment model. The shortcut approach can be expected to lead to a different raking of candidate MPs (Punt et al. 2014), and is intended here only as a development and demonstration tool and will be substituted by the full-feedback evaluation on the JJM-based MP.

7.1 JJM model-based MP (jjms.sa + hockeystick.hcr + splitcatch.is)

This MP extracts from the OM the same set of observations currently employed by the JJM model (SPRFMO 2022b) on catch at age and catch at length, extends the current indices of abundance, and introduces some level of error in all those observations. An input dataset is then prepared that allows the execution of the model executable. All the functions involved in running the model have been defined in the project-specific FLjjm package.

The estimate of spawning stock biomass returned by JJM is then used as input to a *hockey-stick* harvest control rule like the one presented in Figure 7.1. Four arguments determine the strength and points of response of the rule to the estimated stock status.

- Trigger, the value of the input metric (SSB) at which the response variable, in this case catch, starts decreasing for its maximum value.
- Target, the value of the output (catch) employed as a maximum once stock is above the trigger level.
- Minimum, the set minimum level of the output variable that is to be maintained even at low stock status.

- Limit, the point at which the fishery is either stopped or set to the minimum level to allow stock recovery to take place.

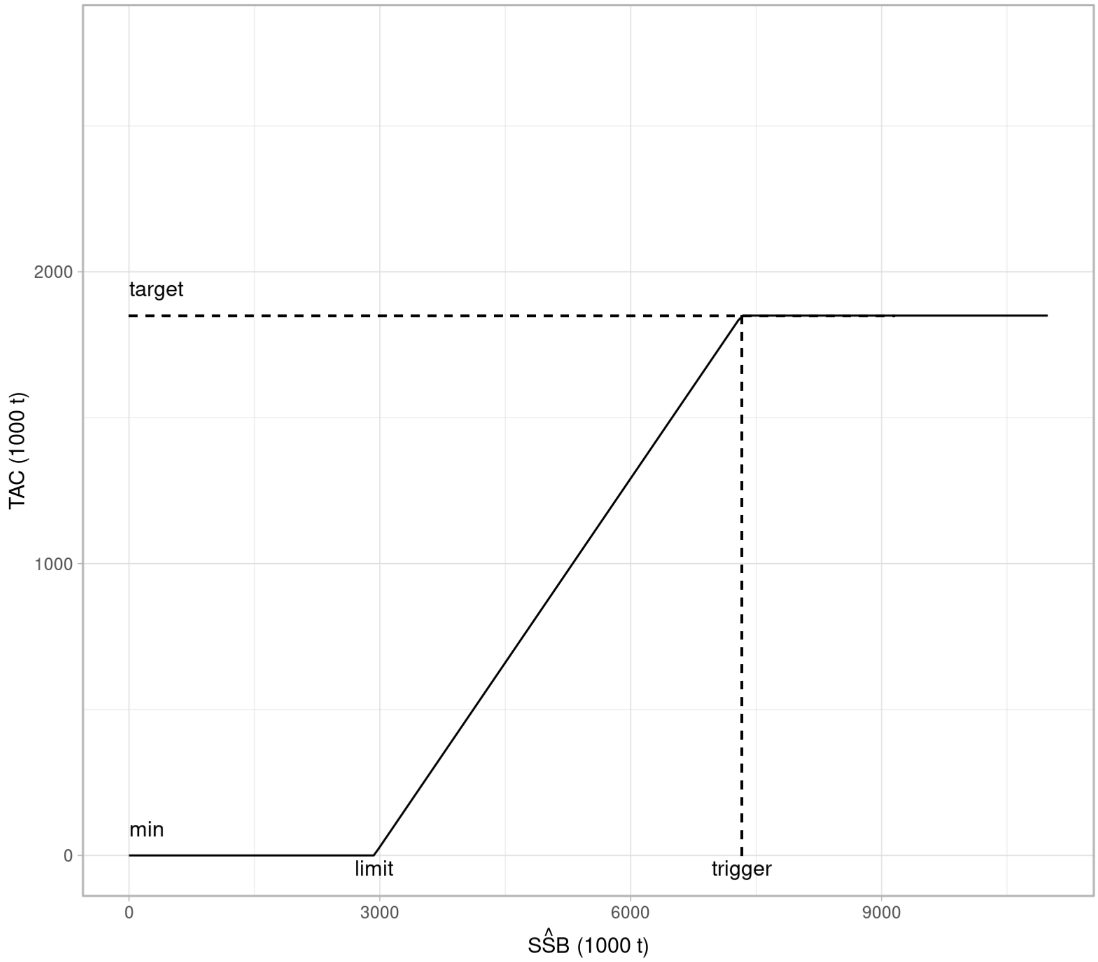

Figure 7.1: Example Harvest Control Rule set by one the tuning exercises for the shortcut stock assessment MP.

7.2 Relative harvest rate MP (cpue.ind + hr.hcr + splitcatch.is)

Harvest rate, the ratio of the total catch over the stock biomass, is a measure of fishing pressure frequently used in stock assessment models and management rules. It provides an equivalent measure to instantaneous fishing mortality on the strength of exploitation of a stock. The concept of relative harvest rate, the ratio of total catch to a relative indicator of stock size (such as a survey index), has been proposed and tested recently for management on stocks for which a stock assessment is unavailable (Fischer et al. 2022). This stock status estimator makes use of the two main data sources: the total catch estimate and the value of a selected index of abundance, assumed to best represent the overall trends in stock biomass.

Harvest rate rules have the potential to be more robust than those built around length-based indicators, as they are less influenced by changes in selectivity, recruitment or environmental factors.

7.3 Assessment shortcut MP (shortcut.sa + hockeystick.hcr + splitcatch.is)

These management procedures require catch advice to be split across the four fleets operating in the fishery by the *splitcath.is* module. No allocation mechanism has been agreed among SPRFMO members. TAC advice is divided among fleets by using their current relative proportions, computed as an average of those reported over the last three years. Any other set of splitting ratios, or an alternative mechanism, can be applied to the simulations if required.

8 Performance statistics

Performance statistics are computed to assess the ability of management procedures to achieve a set of management objectives. A number of metrics of various quantities extracted from either stock or fisheries (e.g. SSB or catch), often combined with relevant reference points (e.g. SSB_{MSY}) or historical values (e.g. catch rates in a certain period), and usually summarized over a period of interest (e.g. as an average over the simulation years), can be computed, either as mean and median values, or as probabilities. They provide objective measures to compare alternative MPs or their ability to obtain the desired objectives, the consequences and trade-offs involved, and the risks involved.

The current set of performance statistics has been defined to inform on the four main axis on which to evaluate the quality of candidate MPs: stock status, conservation risk, catch levels, and variability in catch.

Table 8.1: Performance statistics currently being computed for all runs of the SPRFMO CJM management procedures under evaluation.

Name	Description	Computation
SBMSY	Mean SSB relative to SSB_{MSY}	~yearMeans(SB/SBMSY)
FMSY	Mean fishing mortality relative to F_{MSY}	~yearMeans(F/FMSY)
PSBMSY	Probability of SSB greater or equal to SSB_{MSY}	~yearMeans((SB/SBMSY) >= 1)
PSBlim	Probability that SSB is above B_{lim}	~yearMeans((SB/SBlim) > 1)
C	Mean catch over years	~yearMeans(C)
IACC	Percentage inter-annual change in catch	~100 * yearSums(abs(C[, -1] - C[, -dim(C)[2]]))/yearSums(C)

PC0	Probability of fishery shutdown ($C < MSY \cdot 0.1$)	~yearSums(C < 0.1 * MSY)/dim(C)[2]
green	Probability of being in Kobe green quadrant	~yearSums(FLQuant((SB/SBMSY) > 1 & (F/FMSY) < 1))/dim(SB)[2]

Some of these statistics are also being computed on an annual timestep, so values and trends in time can be compared across MPs. All of them are calculated over certain time periods (short: 3-5 years, medium: 5-10 years, long: > 10 years). For the purposes of tuning, the main management objective is set to be achieved over the 2027-2036 period. The precise definition of these periods should be adjusted to the required time spans over which management objectives are to be achieved. This also allows for the exploration of trade-offs not only across statistics (e.g. mean catch vs. conservation risk) but over time (e.g. short term vs. long term catch).

9 Tuning of management procedures

Management procedures can be set to achieve a primary objective, in a given time frame and with certain probability, by finding the precise value of one of more parameters that are able to alter their performance. This 'tuning' process requires a choice over the primary objective to be made, but the necessary discussion could be informed by observing the effect of alternative objectives on the expected performance and the associated trade-offs.

An initial tuning exercise has been carried out, for demonstration purposes, to determine for a given management procedure (based on a stock assessment shortcut, section 7.1), and set to achieve over the 2027-2036 period probabilities of 50, 60 or 70% of $SB >= SB_{MSY}$ and $F <= F_{MSY}$. This is a performance statistic, usually referred to as being in the *Kobe green* from the 'Kobe' stock status plot agreed by the tuna RFMOs (Merino et al. 2020) and increasingly by other bodies.

9.1 Tuned Management Procedures

An initial set of tuned management procedures is presented here. They cover a single MP type, based on an stock assessment shortcut and a hockey stick-shaped HCR that set a maximum catch level based on the estimate of spawning biomass. Three tuning levels have been, aiming to achieve 50, 60 and 70% average probabilities of the stock status being the green quadrant of the Kobe plot($F \leq F_{MSY}$ and $SB \geq SB_{MSY}$) over the 2027-2036 period.

The time series of recruitment, SSB, catch and fishing mortality (Figure 9.1) for the three tuned MPs show the different expected catch levels, as a positive stock status pushes catches in the long term, to their maximum values. The differences in risks to stock status (Figure 9.2) and overexploitation (9.3) are also fairly clear.

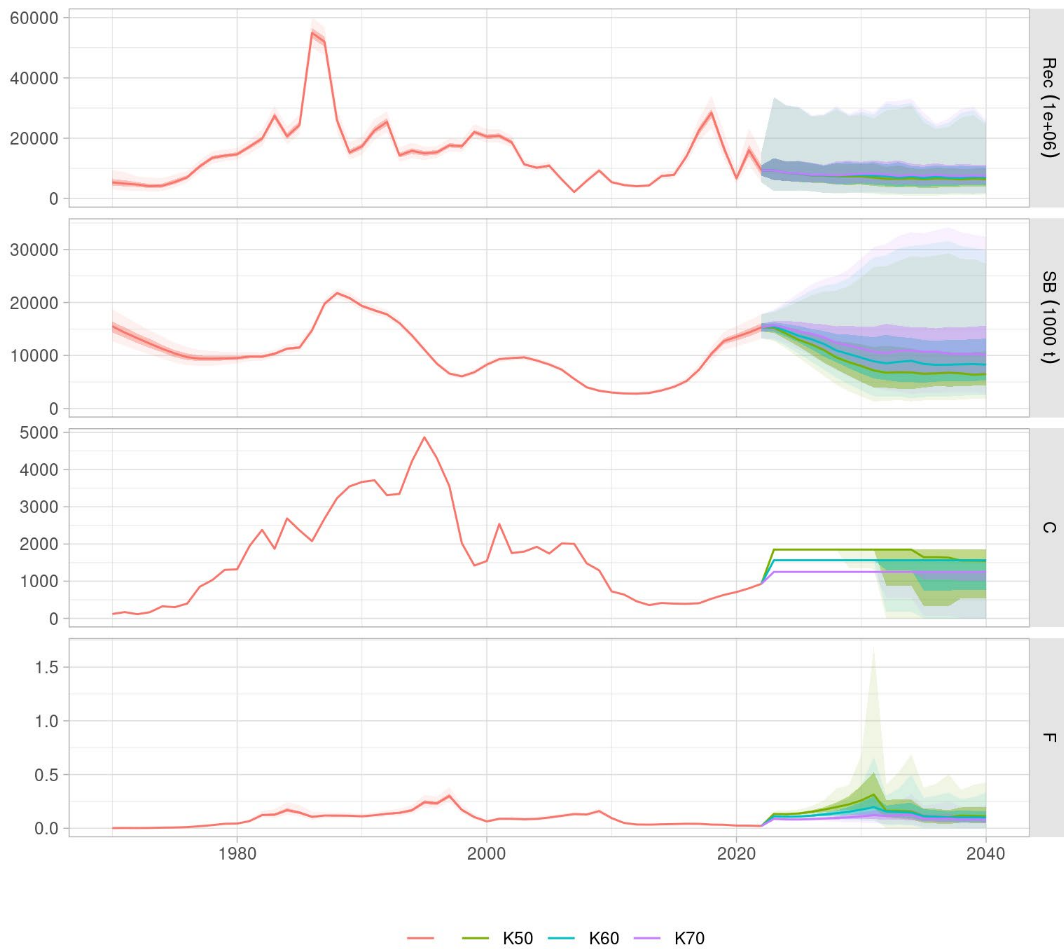

Figure 9.1: Time series of recruitment (Rec), spawning stock biomass (SB), total catch (C) and fishing mortality (F) for the shortcut MP tuned to 50, 60 and 70% probabilities of falling in the Kobe green in the 2027-2036 period.

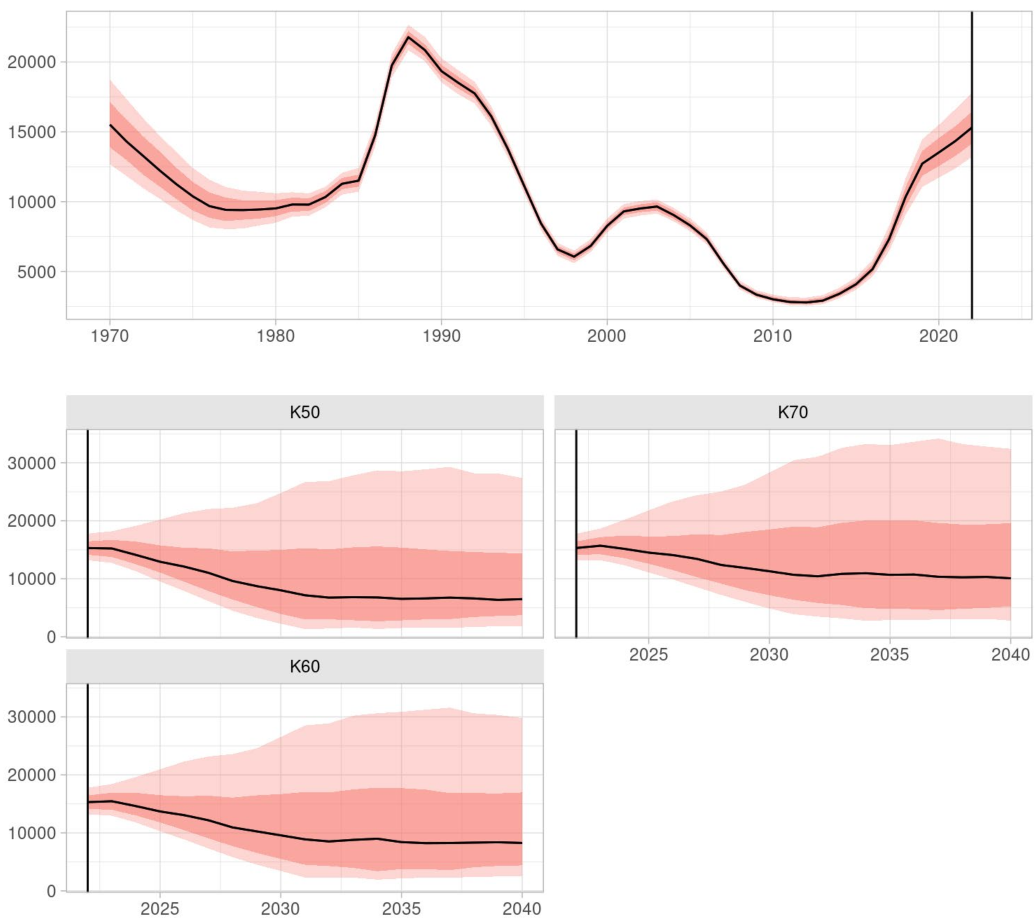

Figure 9.2: Comparison of the trajectories of spawning stock biomass (SB) for conditioned OM (top panel) and the shortcut MP tuned to 50, 60 and 70% probabilities of falling in the Kobe green in the 2027-2036 period (bottom).

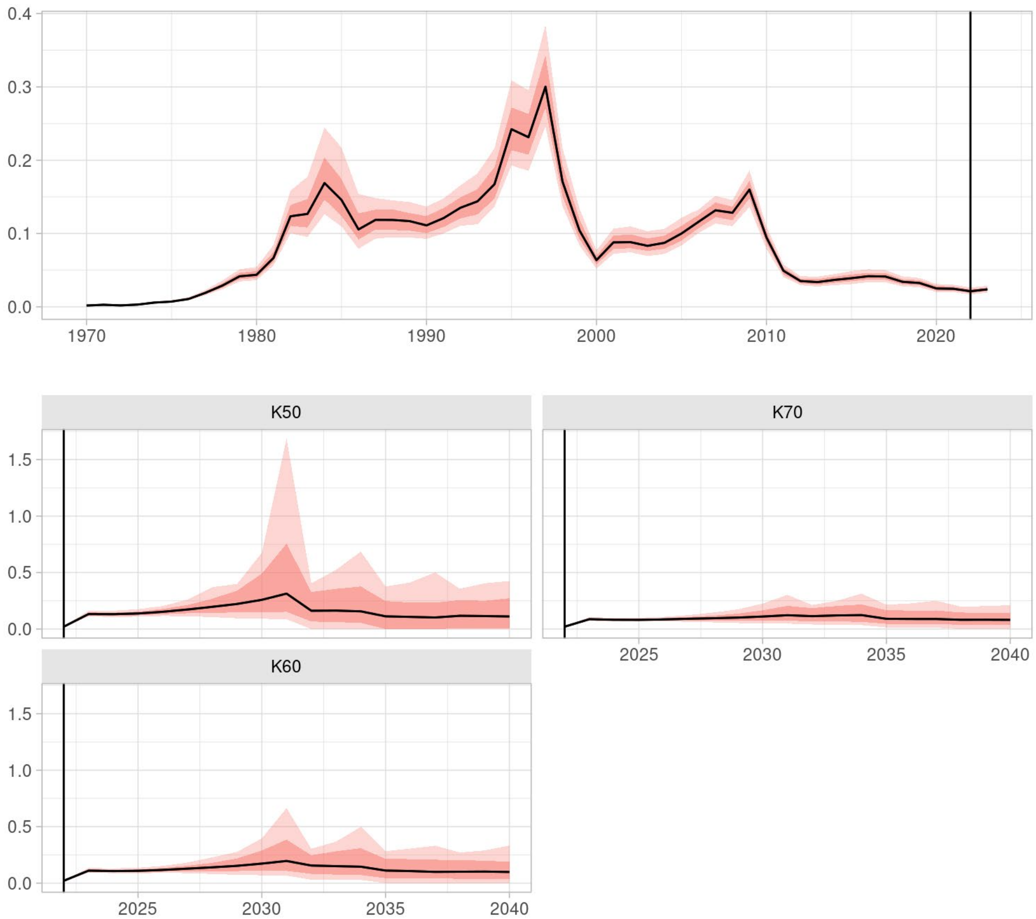

Figure 9.3: Comparison of the trajectories of fishing mortality for conditioned OM (top panel) and the shortcut MP tuned to 50, 60 and 70% probabilities of falling in the Kobe green in the 2027-2036 period (bottom).

The trajectories of spawning biomass against the MSY reference point across all three tuned MPs is presented in Figure 9.4.

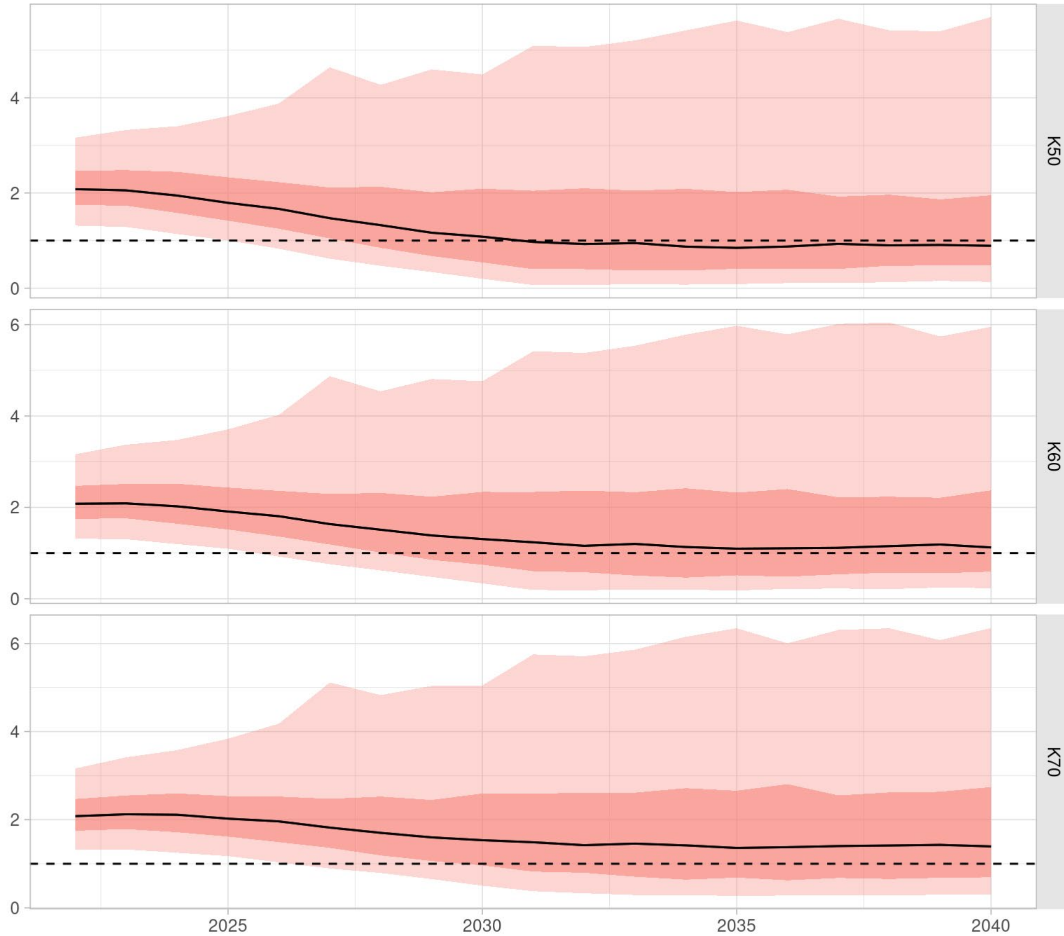

Figure 9.4: Comparison of the trajectories of spawning stock biomass over the MSY reference point (SB/SB_{MSY}) for the shortcut MP tuned to 50, 60 and 70% probabilities of falling in the Kobe green in the 2027-2036 period (bottom).

A standard set of visualizations of all performance statistics is presented now. The boxplots of each statistic across MPs (Figure 9.5) allows a comparison of the expected values and the uncertainty around them for the tuning period.

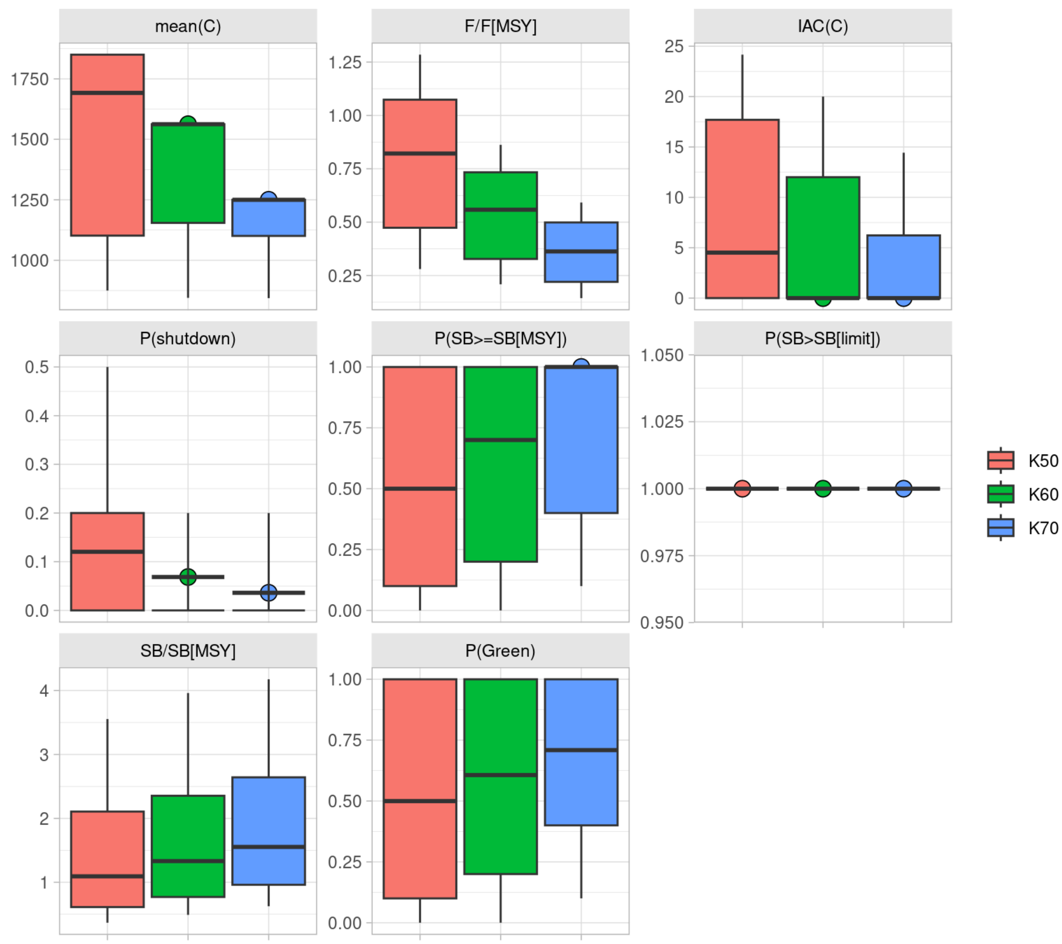

Figure 9.5: Distribution of values for a range of performance statistics computed for the shortcut MP tuned to 50, 60 and 70% probabilities of falling in the Kobe green in the 2027-2036 period (bottom).

A selection of performance statistics, each of them linked to a different perspective of the system (stability, status and risk) are plotted against average annual catch levels so as to explore some of the trade-offs involvedin the selection of a procedure (Figure 9.6).

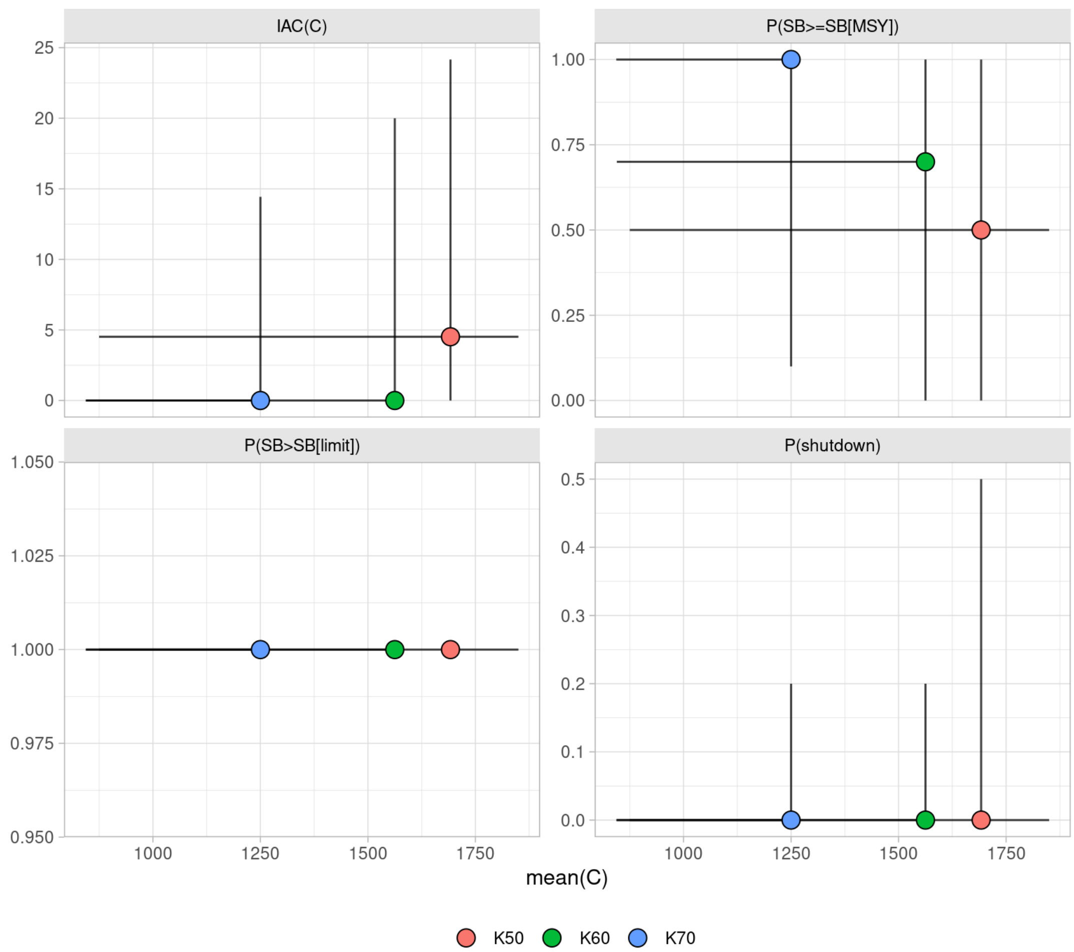

Figure 9.6: Distribution of the values of metrics for fishery stability (IACC, percentage inter-annual change), stock status (P(SB>=SB[MSY]), probability of spawning biomass being greater than SB_{MSY}, conservation risk (P(SB>SB[limit]), probability of spawning biomass greater than 10% of SB_{MSY}), and probability of fishery closure (defined a catch falling below 10% of MSY), against the median catch levels reported by each of shortcut MPs tuned to 50, 60 and 70% probabilities of falling in the Kobe green in the 2027-2036 period.

10 Discussion

10.1 Future steps

10.1.1 OMs

- FINALIZE OM grid with agreed scenarios
  - h
  - (M + growth)
  - OTHER future dynamics

10.1.2MPs

- DEVELOP tuning procedure across 2 OMs based on shortcut
- TEST updated jjm.oem on benchmark model
- RUN test of jjm.sa
- TABLE of MO vs. MP runs for cjm.sa
  - om(h1) + mp(h1)
  - om(h2) + mp(h1)
  - om(h2m) + mp(h1)
  - om(h2) + mp(h1)
  - om(h2) + mp(h2)
  - om(h2m) + mp(h1)
  - om(h2m) + mp(h2)
- MIMIC mixed runs in shortcut (?)

10.1.3MSE

- SET primary (tuning) objective
- AGREE on performance statistics

11 Acknowledgements

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