IOTC Bigeye and Yellowfin Tuna Management Procedure (MP) Evaluation Update Oct 2018

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Summary

This document presents MP evaluation results for bigeye and yellowfin tunas, using the new operating models (OMs) proposed in Kolody and Jumppanen (2018a, b) and the new tuning levels requested by TCMP (2018). The results of various robustness scenarios are included, at this point largely to help facilitate the discussion of their role in the MP development and selection process and how they should be presented to the TCMP.

Introduction

This document presents MP evaluation results for bigeye and yellowfin tunas, using the new operating models (OMs) proposed in Kolody and Jumppanen (2018a, b). These OMs have not yet been endorsed by the formal IOTC technical working parties, but the general approach for defining the OMs was endorsed by the MWP informal MSE working group in March 2018.

The OM software has been modified for improved computational efficiency, with more convenient higher level function access for users (see details in Kolody and Jumppanen (2018b)).

The results are presented with the new tuning levels requested by the second Technical Committee on Management Procedures meeting (TCMP 2018), as detailed in the species-specific sections.

A number of robustness scenarios are presented for both species. This is the first time that robustness scenarios have been presented to the IOTC. Robustness tests refer to simulation tests that are outside of the normal scope of the reference set of OMs, but the term is often used in two different ways. The first is a more informal usage to refer to tests that are done in the process of developing reference set OMs, to test if an uncertainty dimension is important enough to matter. It is common for these robustness scenarios to be either absorbed into the reference set OM if it offers a new and likely challenge, or they may be dropped from further consideration. The second sense is the more formal definition and refers to a particularly challenging scenario that is usually considered unlikely, but plausible, and which could have serious negative consequences for the fishery. Troubling robustness test results may inspire more clever MP development. Differing abilities of MPs to mitigate these serious negative outcomes may provide an additional criterion for selecting among MPs that are otherwise very similar. MPs are not tuned in relation to robustness sets, rather they are tuned for the reference set OM, and it is these tuned MPs that are then re-

tested against the robustness scenarios. The IOTC scientific community needs to prioritize these (and any additional) scenarios carefully, and consider how they should be presented to the TCMP. If there are no code changes required, it is computationally fast to run robustness scenarios (because there is no tuning required). But to present the full set of results for all robustness scenarios to the TCMP would contribute to information overload.

Discussion points for the technical working parties to consider are included in the species-specific sections below.

We have intentionally aimed for a minimalist presentation format that mimics the TCMP standard reports, and expect that the WPTT and WPM might suggest additional details for future presentations to technical audiences.

Management Procedure Definitions

The first character of the candidate MP name designates the model class (e.g. Figure 1, Figure 2), and the following characters refer to the tuning objective, e.g. **M.B18.1 = model-based MP** ("D" indicates data-based MP, "C" indicates constant catch) with **B18.1 tuning** (i.e. the first tuning objective identified for bigeye at the 2018 TCMP). The constant catch scenarios are not real MPs in the sense that they do not respond to observational feedback, but are included for contrast. The MP control parameters are adjusted to achieve the desired management performance across a broad suite of possible future outcomes, and as a result will usually not correspond to the conceptual expectation for any individual simulation result (and are not specifically reported). Figure 10 - Figure 14 and Figure 57 - Figure 59 are an exception to the naming convention, with more descriptive labels to distinguish among multiple model-based and data-based MPs.
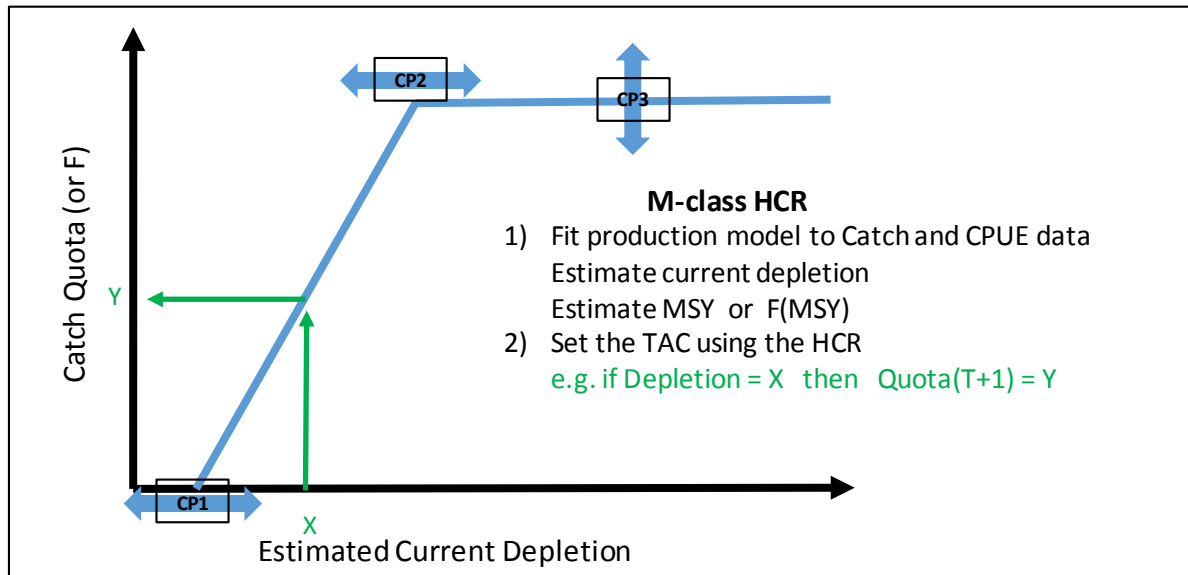
"M" class (model-based) MPs

Figure 1. The model-based (M-class) MPs involve two steps: 1) fitting a simple surplus production model, and 2) applying a Harvest Control Rule (HCR) to the model estimates. The individual M-class MPs differ in terms of the Control Parameters (CP1-CP3) that define the shape of the HCR. In the examples presented here, CP1 and CP2 were constant (at a range of different levels in different candidate MPs), while numerical optimization was used to find the value of CP3 that achieves the precise tuning objective.

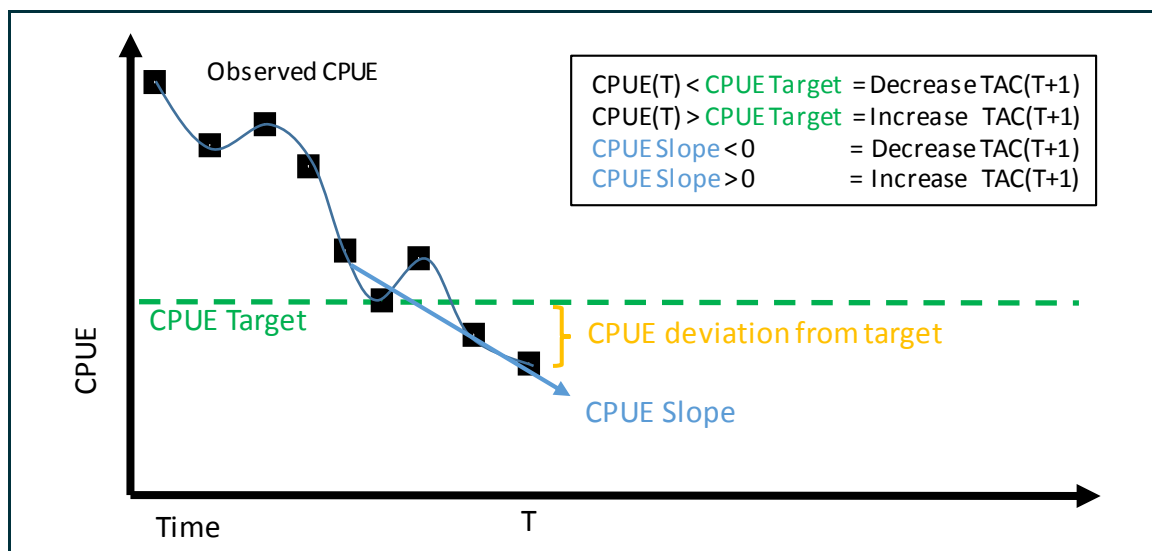**"D" class (data-based or empirical) MPs**

Figure 2. The data-based (D-class) MPs attempt to manage the fishery to achieve a target value of (standardized longline) CPUE. The next TAC is increased relative to the current TAC if current CPUE is above the target CPUE and the CPUE trend is increasing. Conversely, the next TAC is decreased relative to the current TAC if current CPUE is below the target CPUE and the CPUE trend is decreasing. If the CPUE location relative to the target and CPUE slope are in opposite directions, the TAC change could be in either direction, depending on the magnitude of these indicators, and the associated control parameters. Control parameters include: 1) the number of years in the CPUE slope calculation, 2) responsiveness to CPUE target deviation, 3) responsiveness to CPUE slope and 4) the CPUE target (the tuning parameter in this case).

Bigeye Tuna MP evaluation update for WPM 2018

Management Procedure Evaluation Status

- Management Procedure (MP) evaluation is being pursued in the strict sense (i.e. as in the International Whaling Commission and Commission for the Conservation of Southern Bluefin Tuna), in which the data to be input to the MP, the analysis, and the Harvest Control Rule (HCR) are all defined in advance and simulation-tested together.
- The bigeye reference case Operating Model (simulator) is being iteratively developed in line with IOTC technical working party requests (WPTT and WPM). Scientific and technical concerns have been identified in these MP evaluations that require further review.
  - The tests described were run with 252 realizations, and a tuning precision of +/- 1%. Final results for Commission consideration would probably be run with more realizations and higher tuning precision. But we would not expect much difference in the results, except in the tails of the distributions.
- A small set of generic MPs have been evaluated for each of the tuning objectives (see below) requested by the TCMP02 (2018).
- Results from 5 robustness set OMs are presented for bigeye:
  - What happens if the individual fisheries have random and independent TAC implementation errors with a 40% CV? This is equivalent to an aggregate CV of 10% if 15 fisheries were identical (and >10% in the current context).
  - What happens if the fishery ignores the TAC for the first 10 years (i.e. if something is currently preventing the fisheries from catching more fish, they are unlikely to increase effort to attain a quota that is higher than current catch).
  - What happens if all fisheries consistently exceeds the quota by 10% (but report the catch data accurately)?
  - What happens if there are 8 consecutive quarters of poor recruitment immediately after the MP is adopted (e.g. as estimated to have occurred for yellowfin in the early 2000s).
  - What happens if there is a 3% per annum longline catchability trend going forward (with conditioning assumptions unchanged from the reference case)?
- The earliest target date for adoption of an MP was identified as 2019, however it was clear in the TCMP 2018 that further work to illustrate trade-offs and refine management objectives will be required at the TCMP 2019. Scientific and technical support funding has been identified to Dec2019 through the GEF-ABNJ-FAO project and CSIRO, Australia.

Bigeye MP Development Guidance from TCMP02 (2018)

The tuning objective refers to a key management objective that the MPs can achieve precisely (e.g. achieving SB ≥ SB_{MSY} with a 50% probability by 2024). The tuning objective normally relates to a desirable biomass (in terms of the risk of exceeding reference points and/or a rebuilding timeframe), and has a very strong influence on the obtainable yield (because biomass risk and attainable catch are closely related). Tuning ensures that candidate MPs are identical with respect to this high priority objective, making it easier to select among MPs on the basis of performance with respect to secondary management objectives (e.g. yield and catch stability). Ideally the Commission will have narrowed down the tuning objectives to 1 or 2 before MP selection. This will allow MP developers to focus MP development on improving secondary performance characteristics. The TCMP02 defined 3 interim tuning objectives for bigeye:

B18.1: Pr(Kobe green zone 2030:2034) = 0.5. The stock status is in the Kobe green quadrant over the period 2030-2034 exactly 50% of the time (averaged over all simulations).

B18.2: Pr(Kobe green zone 2030:2034) = 0.6. The stock status is in the Kobe green quadrant over the period 2030-2034 exactly 60% of the time (averaged over all simulations).

B18.3: Pr(Kobe green zone 2030:2034) = 0.7. The stock status is in the Kobe green quadrant over the period 2030-2034 exactly 70% of the time (averaged over all simulations).

TCMP02 (2018) recognized the desirability of other MP constraints used in preliminary testing:

- TAC to be set every 3 years (and remain constant between settings)
- A maximum change of 15% to the TAC (increase and decrease) relative to the TAC previously set. This constraint needed to be relaxed to meet the tuning objectives in TCMP01, but was not problematic with the new tuning objectives.

Summary of Bigeye Candidate MP Performance against the reference case OM (OMrefB18.5)

MP results from the reference set OM (OMrefB18.5) are summarized in the standard format in Figure 3 - Figure 9, and Table 1 - Table 2. The previous BET tuning objectives (from TCMP01-2017) were considered undesirable because a rapid TAC increase was required to drive the average biomass down to target levels, with the unintended consequence that biomass was typically depleted at the end of the time period. The new tuning levels (and updated OM) also exhibit this behaviour, though to a reduced degree:

- The most aggressive tuning level, B18.1 is problematic for both of the MPs examined, with large catch increases prescribed over the next decade and median biomass falling below the limit reference point at the end of the time series (2040+).
- The most conservative tuning objective, B18.3, tends to have fairly stable catch trajectories, with median average catches slightly higher than current, and terminal biomass near target levels.
- The intermediate tuning objective B18.2 is intermediate in performance.
- The model-based MP tends to have less biomass risk than the data-based MP. Constant catch MPs have the highest risk levels (and fail to take advantage of surpluses in the more productive scenarios).
- Biomass risk is generally low over the next 20 years (including the 2030-34 tuning period). There is considerable variability in the projected outcomes, but even the lower 10th percentile biomass trajectories appear to be above the biomass limits for the next 10-15 years for all tuning levels. The importance of the pathological behaviour post 2040 should not be too alarming at this stage (it is unlikely that an MP would be retained without review for the next 20 years). It remains true that the only way to bring biomass down to the tuning objectives is to increase catch, but there is still scope for reducing long-term risks in MP design by adjusting responsiveness rates (i.e. as illustrated by the difference between M.B18.2 and D.18.2).
- The contrasting 0 and 1% CPUE catchability trend assumptions represent a stock status uncertainty that increases with time, e.g. if two identical populations are assessed, the abundance estimates will diverge by 10% in 10 years and 35% in 30 years (this is on top of the divergence that is already embedded in the conditioning). If there is no way for an MP to identify a catchability trend, this divergence will lead to progressively larger uncertainty, and

presumably requires a more conservative approach when evaluating over longer time periods.

The preceding points refer to the same example MPs which were presented in TCMP02. However, there is additional scope for MP performance variability within the MP classes defined for a given tuning level. Figure 10 - Figure 14 compare 4 model-based and 4 data-based MPs tuned for the central tuning objective (B18.2). It is ultimately the role of the Commission to select the MPs, but it is important for the technical working parties to provide advice about how the list of candidate MPs should be reduced to a manageable number to be presented to the TCMP, and the scientific advisors to the Commissioners should understand the scope of MP behaviour that is achievable within a tuning objective.

Summary of Bigeye Candidate MP Performance against the robustness tests

OMrobB18.5.CV10 - random TAC implementation error - relatively large (CV = 40%) TAC implementation errors do not make a substantive difference to the MP performance, provided that they are independent among years and fisheries (Figure 15 - Figure 21).

OMrobB18.5.under - 10 years of ignoring the TACs (which is essentially an initial undercatch in the case of BET) does not have an obvious adverse effect on MP performance (Figure 15 - Figure 21). Failing to remove the full TAC results in a slightly higher early biomass. When the TACs do become restrictive, there is no indication of obvious pathological behaviour.

OMrobB18.5.over - A consistent 10% quota over-catch (accurately reported) results in MP performance that is less conservative than the reference set OM (as might be expected), but the MP behaviour is not qualitatively changed.

OMrobB18.5.recShock - a recruitment failure of the magnitude estimated for YFT in the 2000s does not appear to cause a problem for the BET MPs (Figure 36 - Figure 42), presumably in part due to the healthy current stock status. Perhaps counter-intuitively, the recruitment shock might actually reduce the long term biomass risk in some cases, because catch does not need to be increased as much to reach the more aggressive tuning levels.

OMrobB18.5.qTrend3 - if there is an unrecognized 3% per annum increase in longline catchability going forward (i.e. independent of conditioning assumptions), this will have less serious consequences for the MP than might have been expected, if one focuses on the default 20 year performance summary period (Figure 43 - Figure 45). However, the risk of a bad outcome in the latter part of the time series is clearly elevated (Figure 46 - Figure 49). Presumably the effect of the catchability trend would be greater if it was assumed to be occurring during the conditioning period as well. If this is considered to be a plausible scenario, the IOTC scientific community probably needs to seriously consider other methods for monitoring this fishery.

Discussion Points for the 2018 WPM and WPTT

- Assuming that any changes proposed for the reference case OMs do not substantially change the central tendencies of the performance:
  - Should we add additional tuning levels to the TCMP requests, either to i) expand the range of results shown, or ii) suggest that tuning might be pursued in an alternative

currency that is easier to interpret and compare among species and from the standard output graphics (e.g. SB/SBMSY)?

- Are the robustness scenarios tested worth showing to the TCMP and should others be considered? Should the robustness tests be presented differently from the reference case?
- Further examination of MPs:
    - numerical stability of the production model needs to be systematically evaluated. To date, MP performance has been evaluated for a particular implementation, such that: i) there may be scope to improve MP performance if another implementation can make better inferences, and ii) the current MP performance may be predicated on a population model that fails in a particular consistent fashion (re-tuning would be required if a more reliable model was adopted). We have not noted obvious performance problems to date, but deterministic production models often have poor capacity to fit populations with complicated recruitment dynamics.
    - the implications of the divergence between the quota and catch (due to explicit implementation error, or numerical limits to the quota extraction in high F scenarios) on the MP should be examined.
    - If we can obtain more feedback on desirable MP performance characteristics, it may be possible to further customize MP behaviour, e.g. with non-linear relationships or time series structure to help the transition period between current and target stock status.
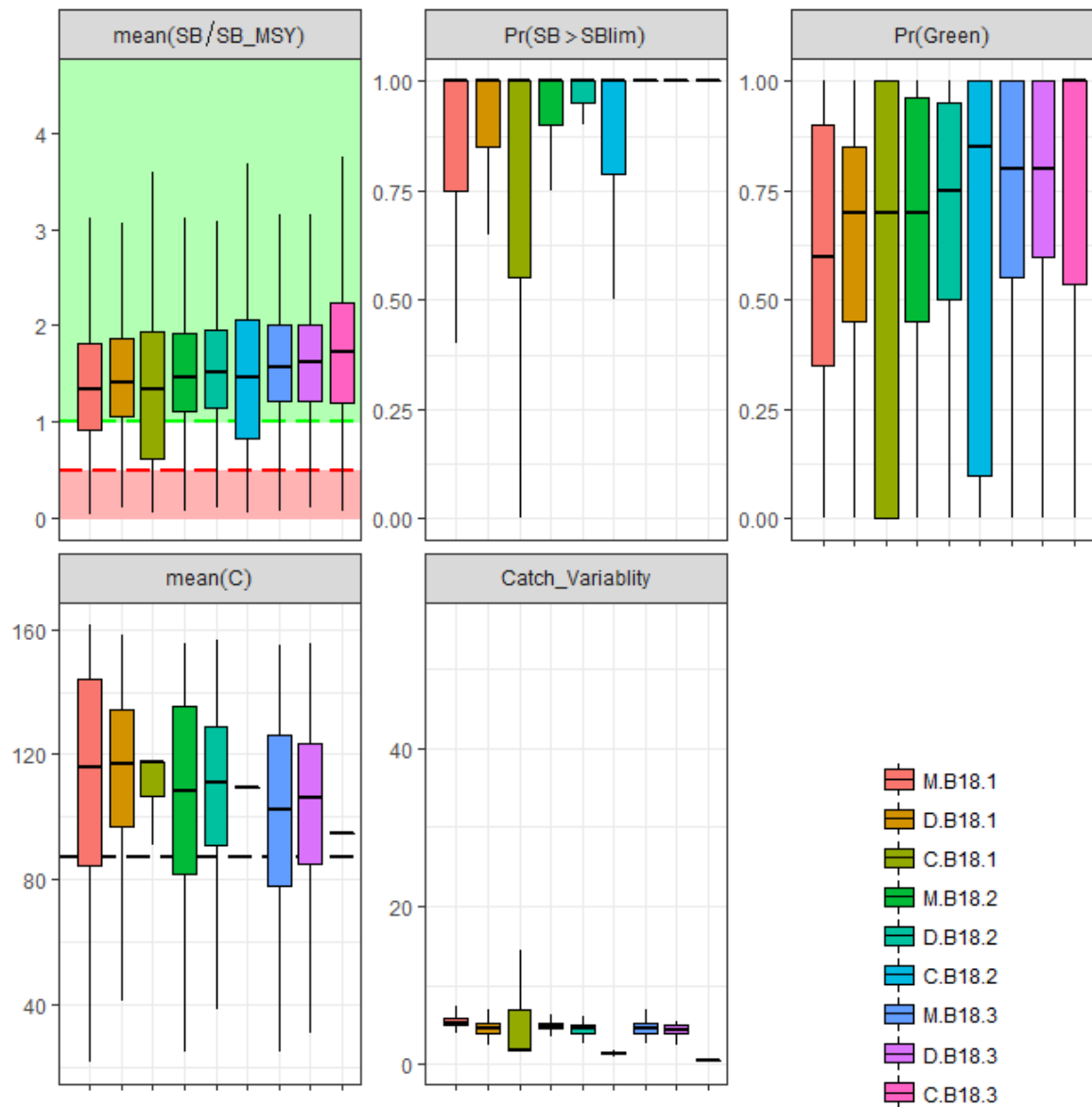
Figure 3. Bigeye reference case (OMrefB18.5) - Boxplots comparing candidate MPs with respect to key performance measures averaged over the period 2019 - 2038. Horizontal line is the median, boxes represent 25th - 75th percentiles, thin lines represent 10th - 90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB$_{MSY}$ performance measure. The horizontal dashed black line is 2016 catch.
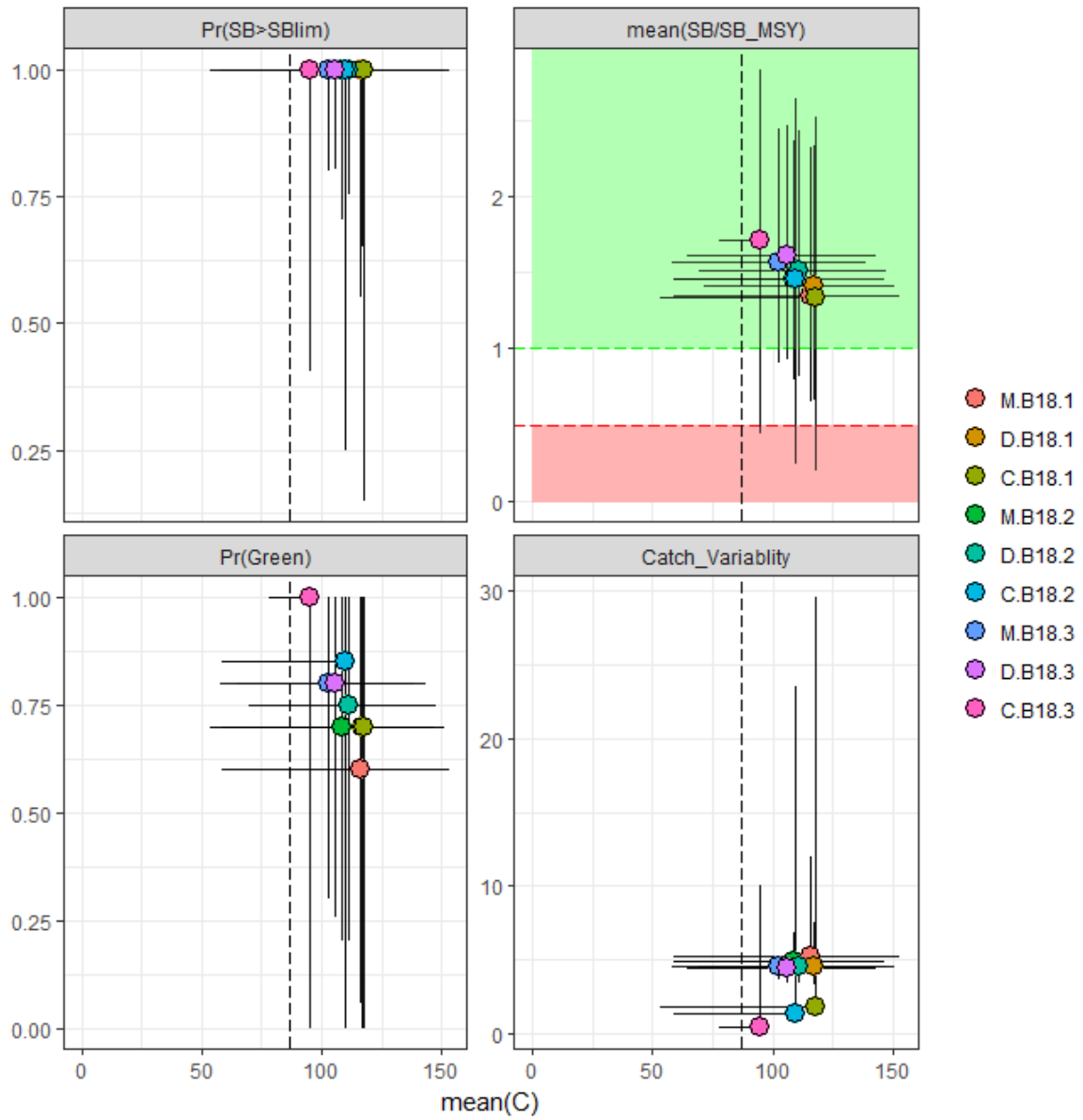
Figure 4. Bigeye reference case (OMrefB18.5) - Trade-off plots comparing candidate MPs with respect to catch on the X-axis, and 4 other key performance measures on the Y-axis, each averaged over the period 2019 - 2038. Circle is the median, lines represent 10th-90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB_{MSY} performance measure. The dashed vertical black line is 2016 catch.
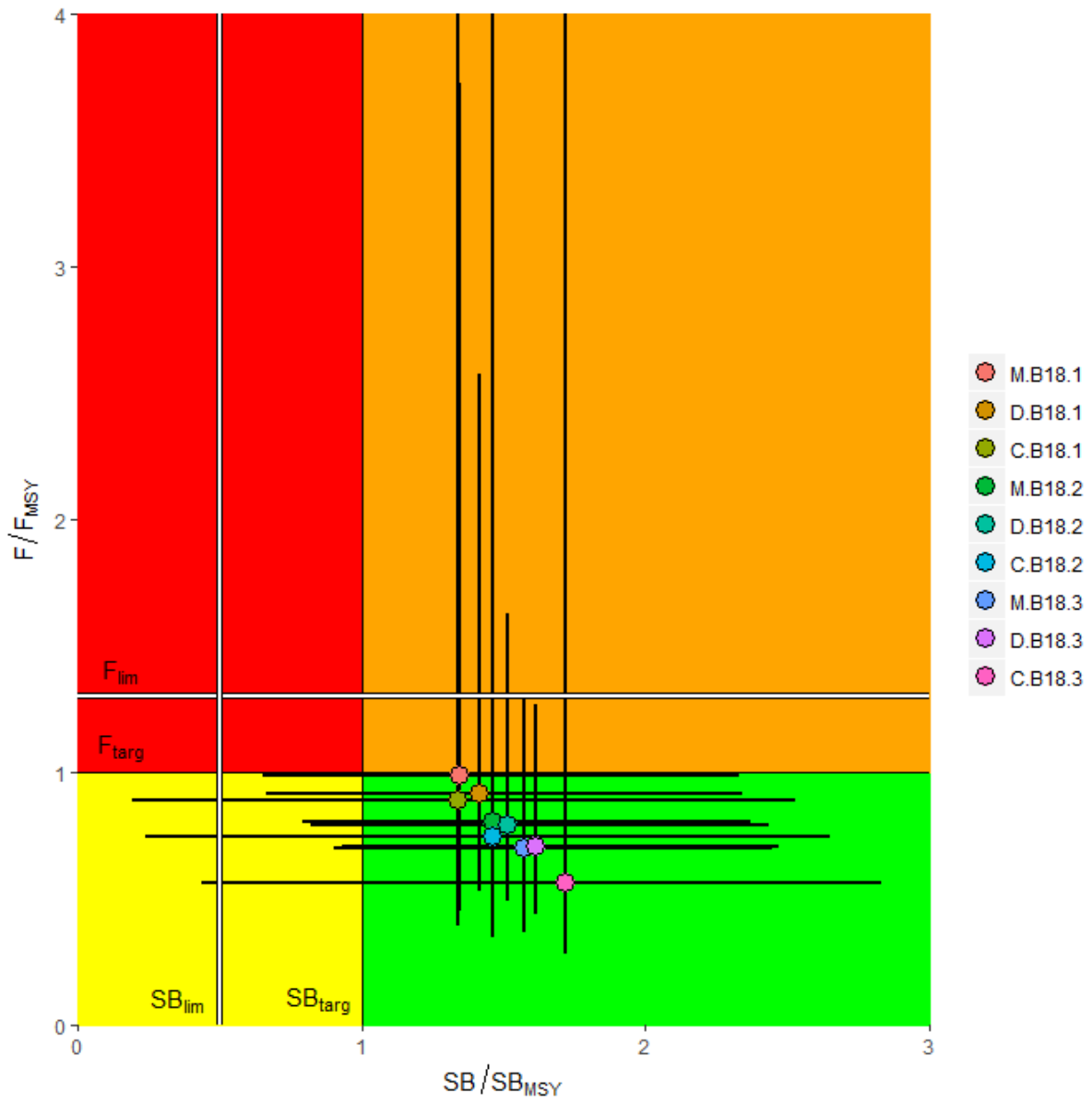
Figure 5. Bigeye reference case (OMrefB18.5) - Kobe plot comparing candidate MPs on the basis of the expected 20 year average (2019-2038) performance. Circle is the median, lines represent 10th-90th percentiles.
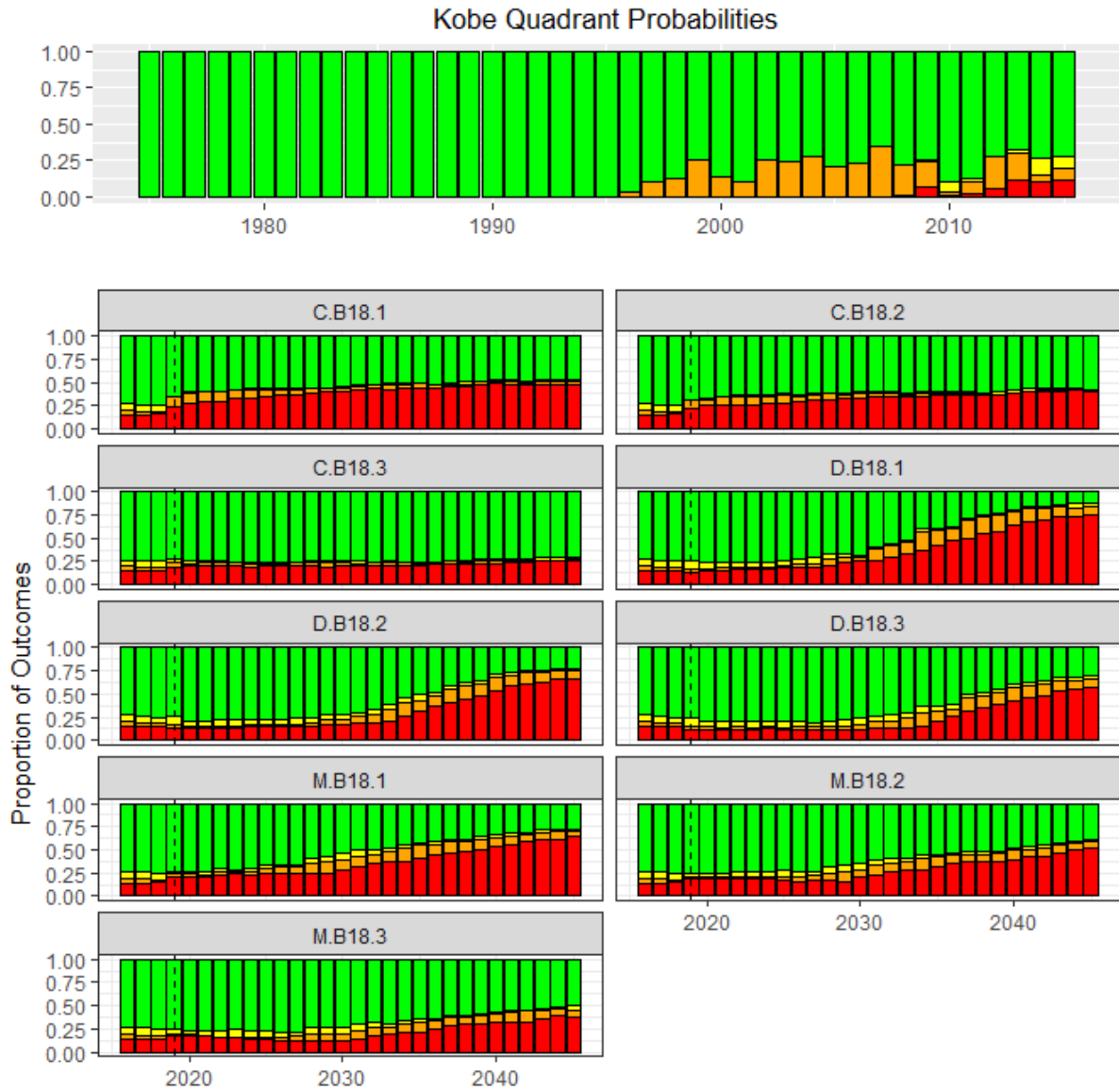
Figure 6.   Bigeye reference case (OMrefB18.5) - Proportion of simulations in each of the Kobe quadrants over time for each of the candidate MPs. Historical estimates are included in the top panel. The lower panels are projections, with the first MP application indicated by the broken vertical line (2019).
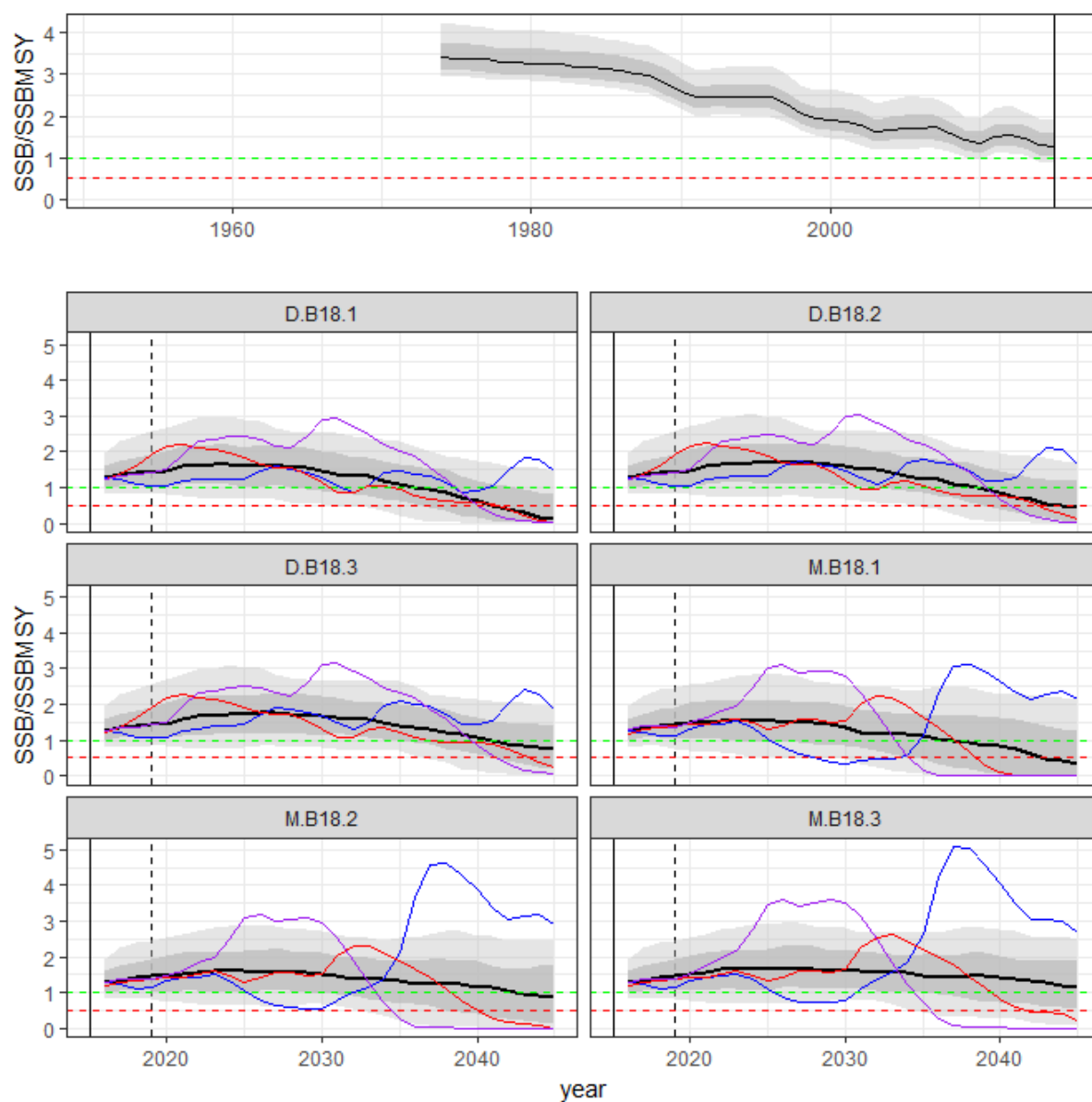
Figure 7. Bigeye reference case (OMrefB18.5) - Time series of spawning stock size for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
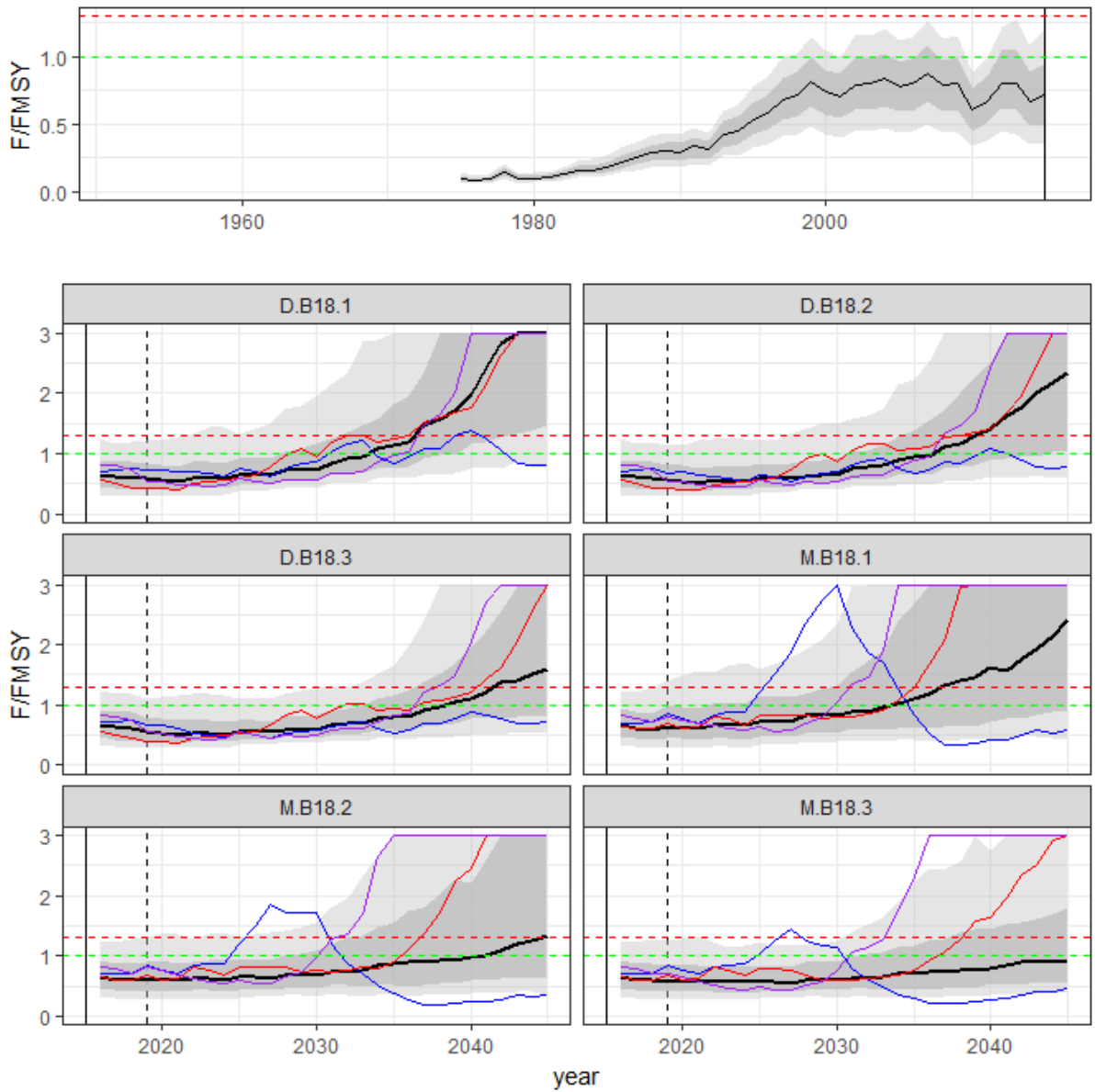
Figure 8. Bigeye reference case (OMrefB18.5) - Time series of fishing intensity (Upper bound truncated at F = 3) for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
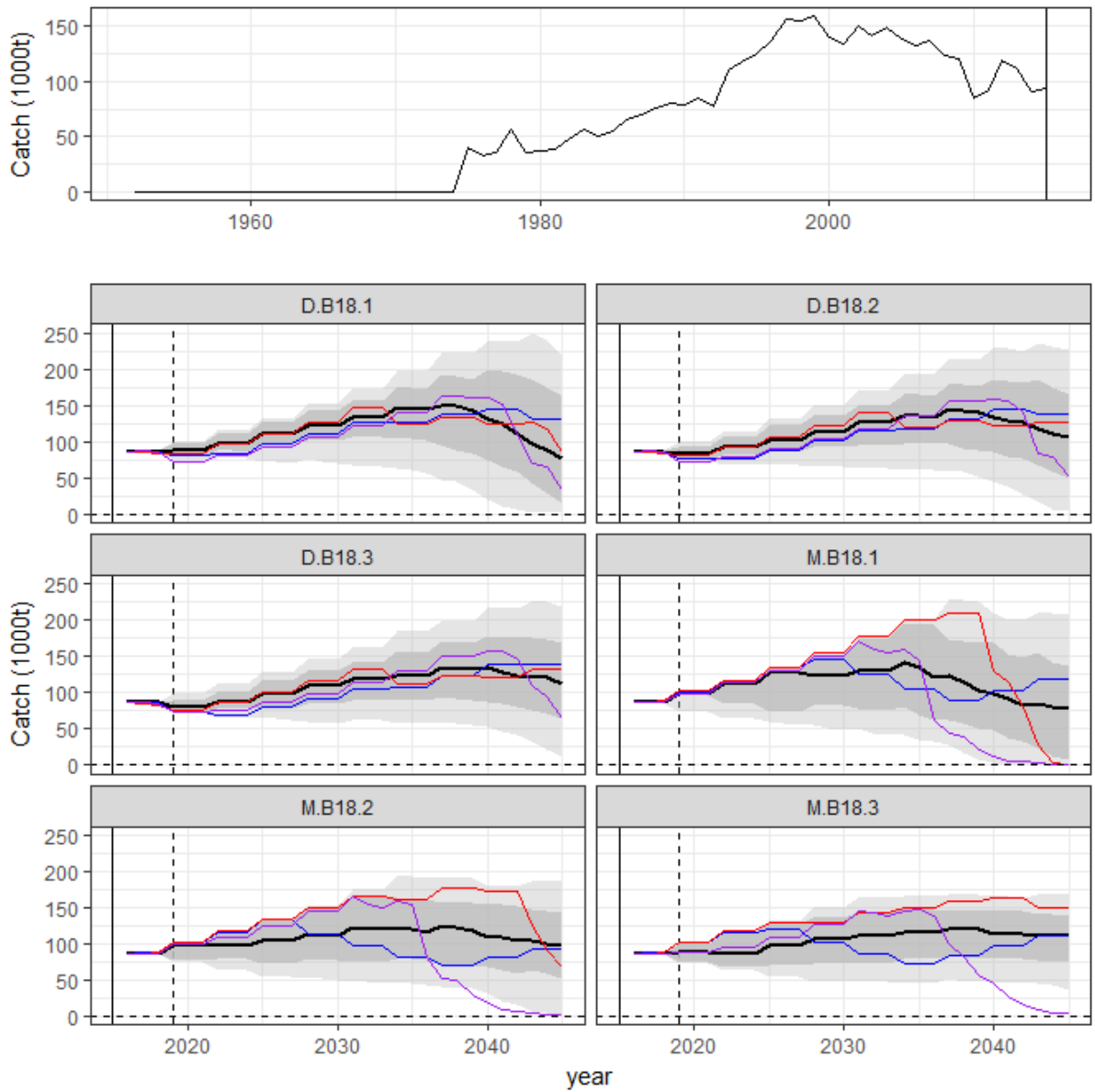
Figure 9. Bigeye reference case (OMrefB18.5) - Time series of catch for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. The broken black horizontal line represents recent (2016) catch. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.

Table 1. Bigeye reference case (OMrefB18.5) - Performance of candidate MPs with respect to key performance measures (averaged over the period 2019-2038). Shading indicates the relative performance (darker = better).

	Performance Measure				
Management Procedure	SB/SB_{MSY}	Prob(Green)	Prob(SB>limit)	Mean Catch	Catch Variability
M.B18.1	1.34 (0.63-1.94)	0.55	0.78	117.7 (106.4-117.7)	1.84
D.B18.1	1.46 (0.83-2.06)	0.62	0.83	109.5 (109.5-109.6)	1.35
C.B18.1	1.72 (1.21-2.24)	0.74	0.90	94.9 (94.8-94.9)	0.49
M.B18.2	1.42 (1.06-1.86)	0.61	0.89	116.9 (96.7-134.4)	4.58
D.B18.2	1.52 (1.15-1.95)	0.68	0.93	111.0 (91.0-128.7)	4.53
C.B18.2	1.62 (1.23-2.01)	0.73	0.95	106.0 (85.2-123.5)	4.41
M.B18.3	1.35 (0.93-1.81)	0.58	0.85	115.9 (84.3-144.4)	5.25
D.B18.3	1.46 (1.12-1.92)	0.66	0.91	108.4 (81.8-135.4)	4.85
C.B18.3	1.58 (1.23-2.00)	0.72	0.94	102.6 (78.1-126.1)	4.56

Table 2a. Bigeye reference case (OMrefB18.5) - Candidate MP performance for standard IOTC performance measures for the year 2019.

Status : maximise stock status		1 year average								
		M.B18.1	D.B18.1	C.B18.1	M.B18.2	D.B18.2	C.B18.2	M.B18.3	D.B18.3	C.B18.3
Mean spawner biomass relative to pristine	SB/SB_0	0.39	0.40	0.40	0.39	0.39	0.39	0.40	0.40	0.40
Minimum spawner biomass relative to pristine	SB/SB_0	0.39	0.40	0.40	0.39	0.39	0.39	0.40	0.40	0.40
Mean spawner biomass relative to SBMSY	SB/SB_{MSY}	1.42	1.43	1.44	1.42	1.43	1.43	1.45	1.46	1.47
Mean fishing mortality relative to FMSY	F/F_{tar}	0.78	0.72	0.62	0.58	0.56	0.54	0.63	0.60	0.58
Mean fishing mortality relative to target	F/F_{MSY}	0.78	0.72	0.62	0.58	0.56	0.54	0.63	0.60	0.58
Probability of being in Kobe green quadrant	SB,F	0.64	0.69	0.75	0.75	0.75	0.76	0.73	0.75	0.75
Probability of being in Kobe red quadrant	SB,F	0.23	0.23	0.20	0.13	0.12	0.12	0.21	0.19	0.17
Safety : maximise the probability of remaining above low stock status (i.e. minimise risk)										
Probability of spawner biomass being above 20% of SB0	SB	0.92	0.93	0.93	0.93	0.94	0.94	0.92	0.92	0.92
Probability of spawner biomass being above BLim	SB	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99
Yield : maximise catches across regions and gears										
Mean catch (1000 t)	C	117.71	109.54	94.86	87.50	83.93	79.71	99.02	97.74	88.91
Mean relative CPUE (aggregate)	C	1.07	1.00	0.86	0.76	0.74	0.71	0.88	0.85	0.80
Mean catch relative to MSY	C/MSY	0.88	0.88	0.89	0.92	0.92	0.92	0.89	0.90	0.90
Stability: maximise stability in catches to reduce commercial uncertainty										
Mean absolute proportional change in catch	C	35.65	26.23	9.31	9.66	11.72	13.56	15.00	15.00	15.00
% Catch coefficient of variation	C	NA	NA	NA	NA	NA	NA	NA	NA	NA
Probability of shutdown	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table2c. Bigeye reference case (OMrefB18.5) - Candidate MP performance for standard IOTC performance measures for the 5 year period 2019-2023.

Status : maximise stock status		5 year average								
		M.B18. 1	D.B18. 1	C.B18. 1	M.B18. 2	D.B18. 2	C.B18. 2	M.B18. 3	D.B18. 3	C.B18. 3
Mean spawner biomass relative to pristine	SB/SB_0	0.37	0.38	0.40	0.43	0.43	0.44	0.42	0.42	0.43
Minimum spawner biomass relative to pristine	SB/SB_0	0.32	0.33	0.36	0.36	0.36	0.37	0.37	0.37	0.37
Mean spawner biomass relative to SBMSY	SB/SB_{MSY}	1.39	1.44	1.52	1.57	1.59	1.60	1.49	1.51	1.57
Mean fishing mortality relative to FMSY	F/F_{tar}	0.80	0.72	0.59	0.59	0.55	0.53	0.64	0.61	0.57
Mean fishing mortality relative to target	F/F_{MSY}	0.80	0.72	0.59	0.59	0.55	0.53	0.64	0.61	0.57
Probability of being in Kobe green quadrant	SB,F	0.61	0.65	0.74	0.76	0.78	0.79	0.72	0.75	0.77
Probability of being in Kobe red quadrant	SB,F	0.29	0.26	0.20	0.15	0.13	0.12	0.22	0.19	0.16
Safety : maximise the probability of remaining above low stock status (i.e. minimise risk)										
Probability of spawner biomass being above 20% of SB0	SB	0.84	0.86	0.90	0.92	0.92	0.93	0.87	0.89	0.89
Probability of spawner biomass being above BLim	SB	0.91	0.94	0.96	0.97	0.97	0.97	0.95	0.96	0.97
Yield : maximise catches across regions and gears										
Mean catch (1000 t)	C	117.71	109.54	94.86	90.73	86.71	82.27	103.53	96.63	89.14
Mean relative CPUE (aggregate)	C	1.07	1.00	0.86	0.80	0.75	0.73	0.91	0.86	0.81
Mean catch relative to MSY	C/MSY	0.88	0.90	0.94	0.94	0.95	0.95	0.94	0.95	0.96
Stability: maximise stability in catches to reduce commercial uncertainty										
Mean absolute proportional change in catch	C	7.19	5.28	1.88	4.56	4.71	4.66	6.00	6.00	6.00
% Catch coefficient of variation	C	0.00	0.00	0.00	0.08	0.08	0.08	0.08	0.08	0.08
Probability of shutdown	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2d. Bigeye reference case (OMrefB18.5) - Candidate MP performance for standard IOTC performance measures for the 10 year period 2019-2029.

Status : maximise stock status		10 year average								
		M.B18.1	D.B18.1	C.B18.1	M.B18.2	D.B18.2	C.B18.2	M.B18.3	D.B18.3	C.B18.3
Mean spawner biomass relative to pristine	SB/SB_0	0.37	0.40	0.43	0.44	0.45	0.46	0.40	0.43	0.45
Minimum spawner biomass relative to pristine	SB/SB_0	0.28	0.31	0.34	0.32	0.33	0.34	0.30	0.32	0.33
Mean spawner biomass relative to SBMSY	SB/SB_{MSY}	1.35	1.44	1.61	1.60	1.64	1.67	1.52	1.57	1.64
Mean fishing mortality relative to FMSY	F/F_{tar}	0.81	0.72	0.58	0.63	0.57	0.54	0.71	0.65	0.59
Mean fishing mortality relative to target	F/F_{MSY}	0.81	0.72	0.58	0.63	0.57	0.54	0.71	0.65	0.59
Probability of being in Kobe green quadrant	SB,F	0.59	0.64	0.75	0.74	0.77	0.80	0.69	0.73	0.77
Probability of being in Kobe red quadrant	SB,F	0.33	0.28	0.20	0.17	0.14	0.12	0.23	0.18	0.15
Safety : maximise the probability of remaining above low stock status (i.e. minimise risk)										
Probability of spawner biomass being above 20% of SB0	SB	0.78	0.82	0.88	0.90	0.92	0.93	0.85	0.88	0.89
Probability of spawner biomass being above BLim	SB	0.86	0.89	0.93	0.96	0.96	0.97	0.92	0.95	0.96
Yield : maximise catches across regions and gears										
Mean catch (1000 t)	C	117.71	109.54	94.86	100.50	94.70	88.22	114.31	100.55	91.57
Mean relative CPUE (aggregate)	C	1.05	0.99	0.86	0.87	0.82	0.79	0.94	0.88	0.84
Mean catch relative to MSY	C/MSY	0.89	0.92	1.01	1.00	1.02	1.04	0.96	0.99	0.99
Stability: maximise stability in catches to reduce commercial uncertainty										
Mean absolute proportional change in catch	C	3.62	2.67	0.95	4.99	4.98	4.97	6.00	6.00	5.74
% Catch coefficient of variation	C	0.00	0.00	0.00	0.14	0.14	0.13	0.15	0.15	0.14
Probability of shutdown	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2e. Bigeye reference case (OMrefB18.5) - Candidate MP performance for standard IOTC performance measures for the 20 year period 2019-2038.

| Status : maximise stock status		20 year average								
		M.B18.1	D.B18.1	C.B18.1	M.B18.2	D.B18.2	C.B18.2	M.B18.3	D.B18.3	C.B18.3
Mean spawner biomass relative to pristine	SB/SB_0	0.35	0.40	0.46	0.38	0.41	0.43	0.36	0.40	0.43
Minimum spawner biomass relative to pristine	SB/SB_0	0.21	0.25	0.30	0.16	0.20	0.23	0.15	0.19	0.23
Mean spawner biomass relative to SBMSY	SB/SB_{MSY}	1.34	1.46	1.72	1.42	1.52	1.62	1.35	1.46	1.58
Mean fishing mortality relative to FMSY	F/F_{tar}	0.89	0.74	0.56	0.92	0.79	0.70	0.98	0.80	0.70
Mean fishing mortality relative to target	F/F_{MSY}	0.89	0.74	0.56	0.92	0.79	0.70	0.98	0.80	0.70
Probability of being in Kobe green quadrant	SB,F	0.55	0.62	0.74	0.61	0.68	0.73	0.58	0.66	0.72
Probability of being in Kobe red quadrant	SB,F	0.38	0.32	0.20	0.27	0.20	0.16	0.31	0.23	0.17
Safety : maximise the probability of remaining above low stock status (i.e. minimise risk)										
Probability of spawner biomass being above 20% of SB0	SB	0.71	0.76	0.85	0.81	0.87	0.90	0.77	0.83	0.88
Probability of spawner biomass being above BLim	SB	0.78	0.83	0.90	0.89	0.93	0.95	0.85	0.91	0.94
Yield : maximise catches across regions and gears										
Mean catch (1000 t)	C	117.69	109.53	94.86	116.86	111.04	105.96	115.95	108.42	102.58
Mean relative CPUE (aggregate)	C	0.95	0.91	0.83	1.02	0.96	0.91	0.98	0.94	0.88
Mean catch relative to MSY	C/MSY	0.85	0.94	1.08	0.92	0.96	1.03	0.86	0.93	1.00
Stability: maximise stability in catches to reduce commercial uncertainty										
Mean absolute proportional change in catch	C	1.84	1.35	0.49	4.58	4.53	4.41	5.25	4.85	4.56
% Catch coefficient of variation	C	0.00	0.00	0.00	0.24	0.23	0.21	0.23	0.21	0.18
Probability of shutdown	C	0.07	0.05	0.03	0.01	0.00	0.00	0.02	0.01	0.00
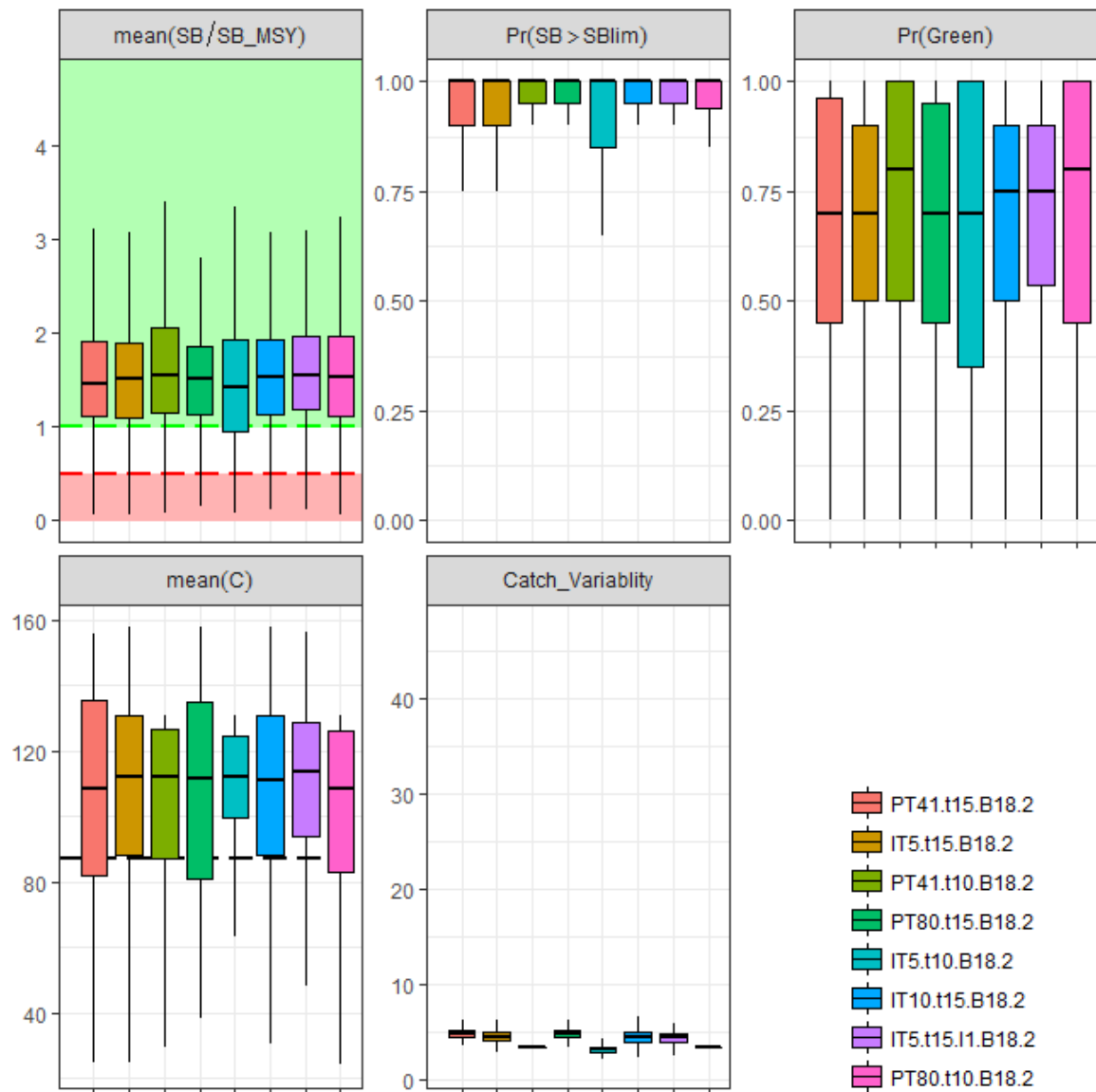
Figure 10. Bigeye reference case (OMrefB18.5) - Boxplots comparing a suite of model-based and data-based candidate MPs with respect to key performance measures averaged over the period 2019 - 2038, tuning objective B18.2 only. Horizontal line is the median, boxes represent 25th - 75th percentiles, thin lines represent 10th - 90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB$_{MSY}$ performance measure. The horizontal dashed black line is 2016 catch.
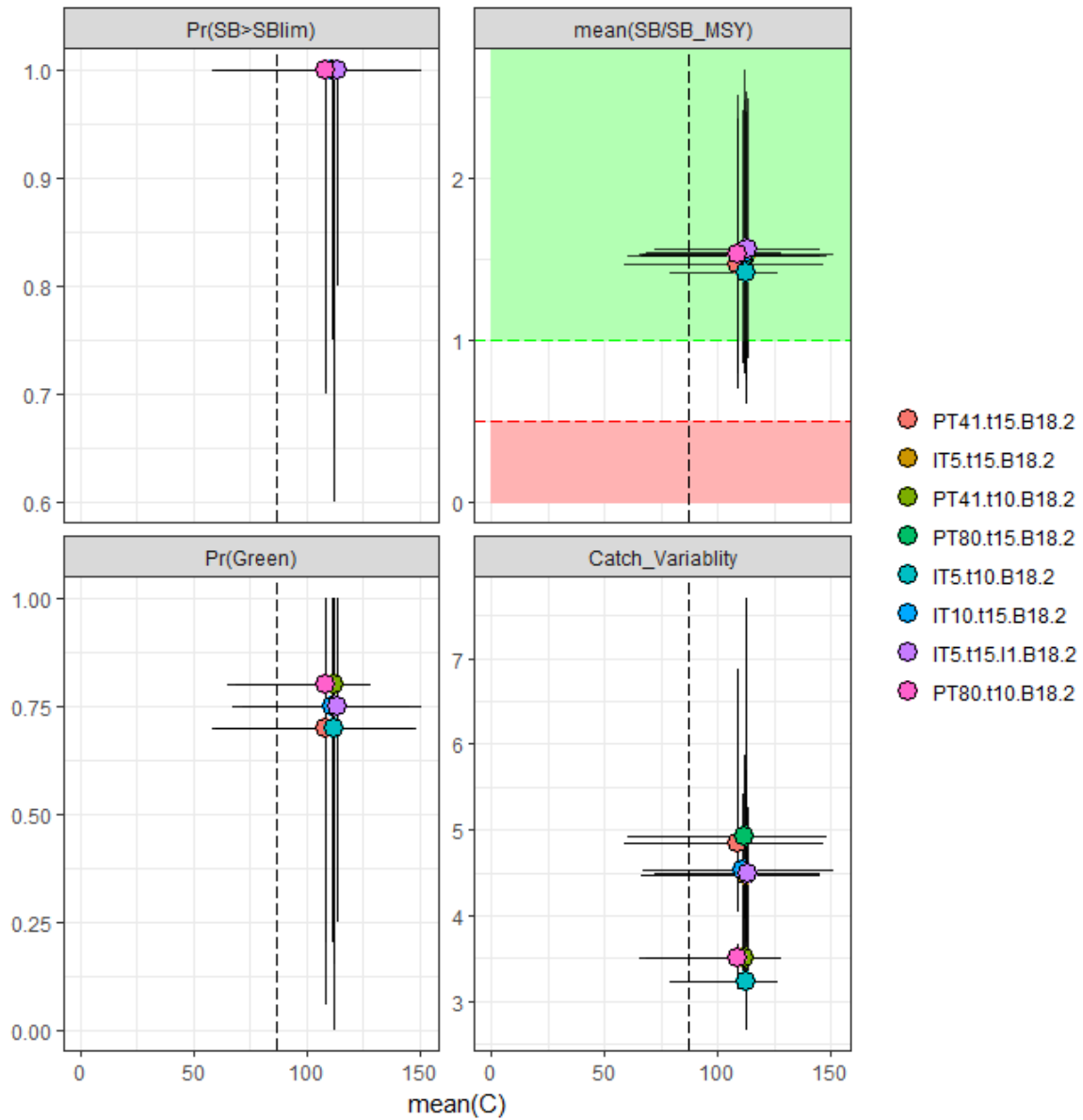
Figure 11. Bigeye reference case (OMrefB18.5) - Trade-off plots comparing a suite of model-based and data-based candidate MPs with respect to catch on the X-axis, and 4 other key performance measures on the Y-axis, each averaged over the period 2019 - 2038, tuning objective B18.2 only. Circle is the median, lines represent 10th-90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB$_{MSY}$ performance measure. The dashed vertical black line is 2016 catch.
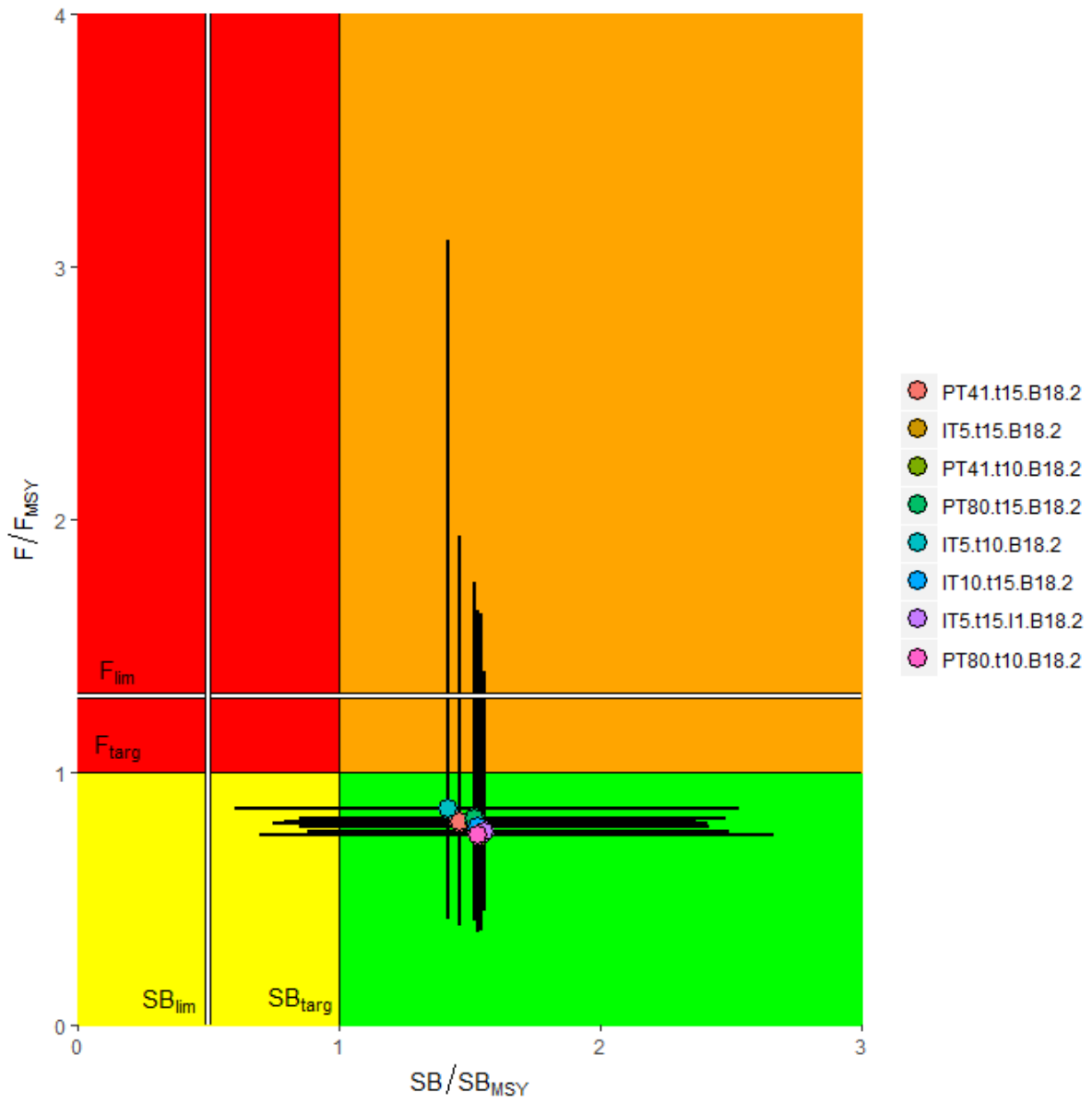
Figure 12. Bigeye reference case (OMrefB18.5) - Kobe plot comparing a suite of model-based and data-based candidate MPs on the basis of the expected 20 year average (2019-2038) performance, tuning objective B18.2 only. Circle is the median, lines represent 10th-90th percentiles.
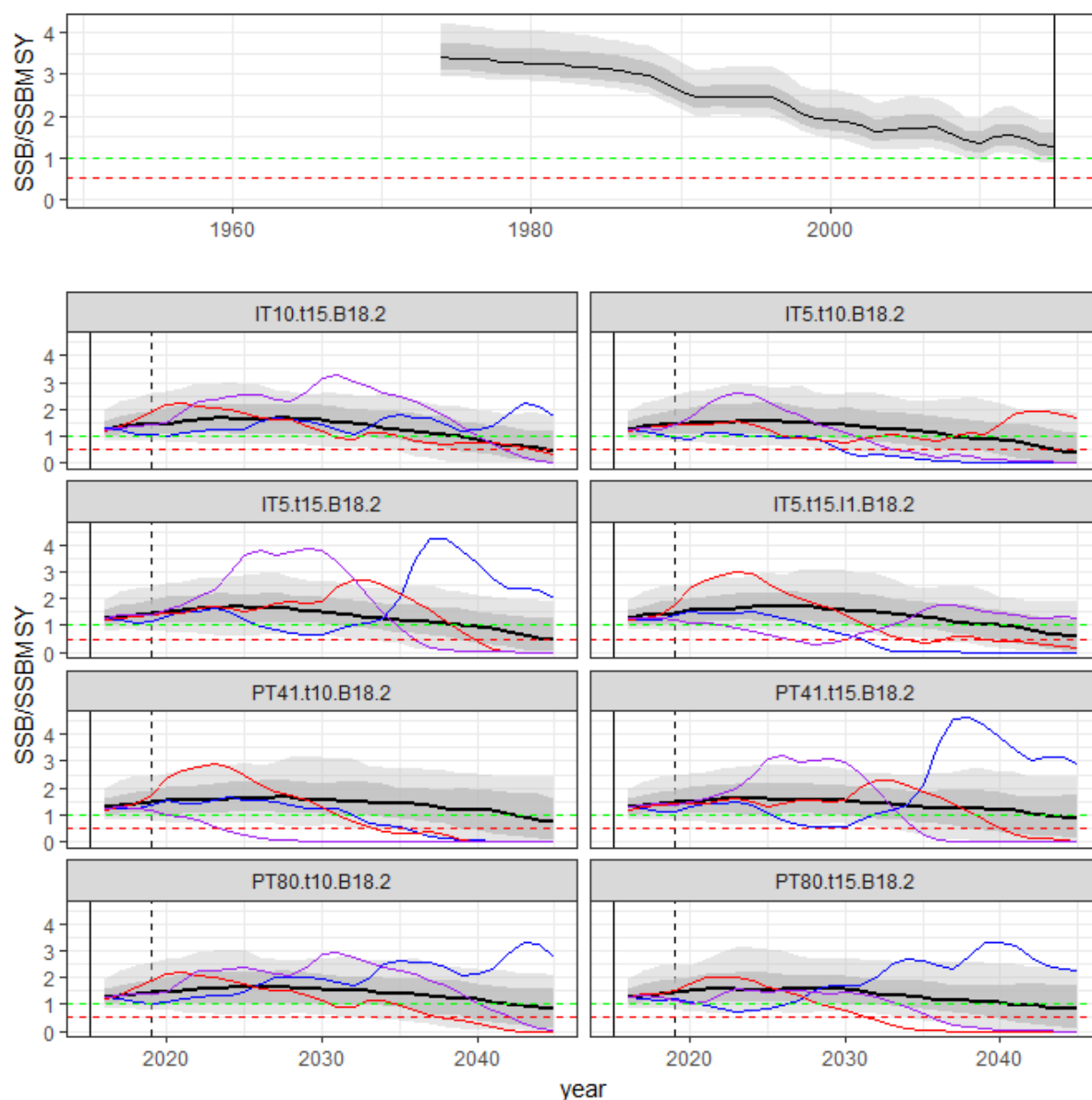
Figure 13. Bigeye reference case (OMrefB18.5) - Time series of spawning stock size for a suite of model-based and data-based candidate MPs, tuning objective B18.2 only. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.

Figure 14. Bigeye reference case (OMrefB18.5) - Time series of catch for a suite of model-based and data-based candidate MPs MPs, tuning objective B18.2 only. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. The broken black horizontal line represents recent (2016) catch. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
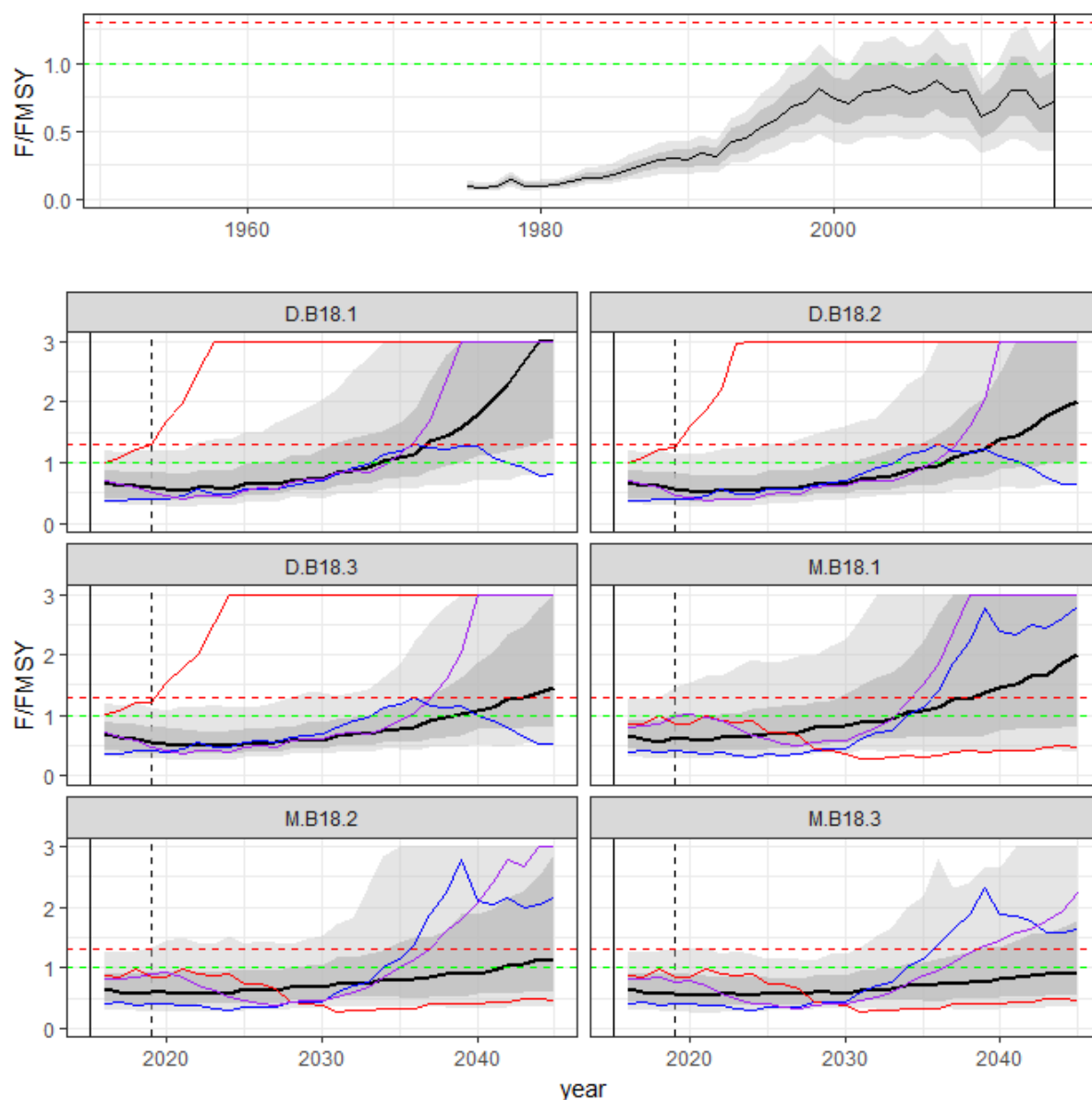
Figure 15. Bigeye robustness case (OMrobB18.5.impErrCV10 - random implementation error) - Boxplots comparing candidate MPs with respect to key performance measures averaged over the period 2019 - 2038. Horizontal line is the median, boxes represent 25th - 75th percentiles, thin lines represent 10th - 90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB$_{MSY}$ performance measure. The horizontal dashed black line is 2016 catch.
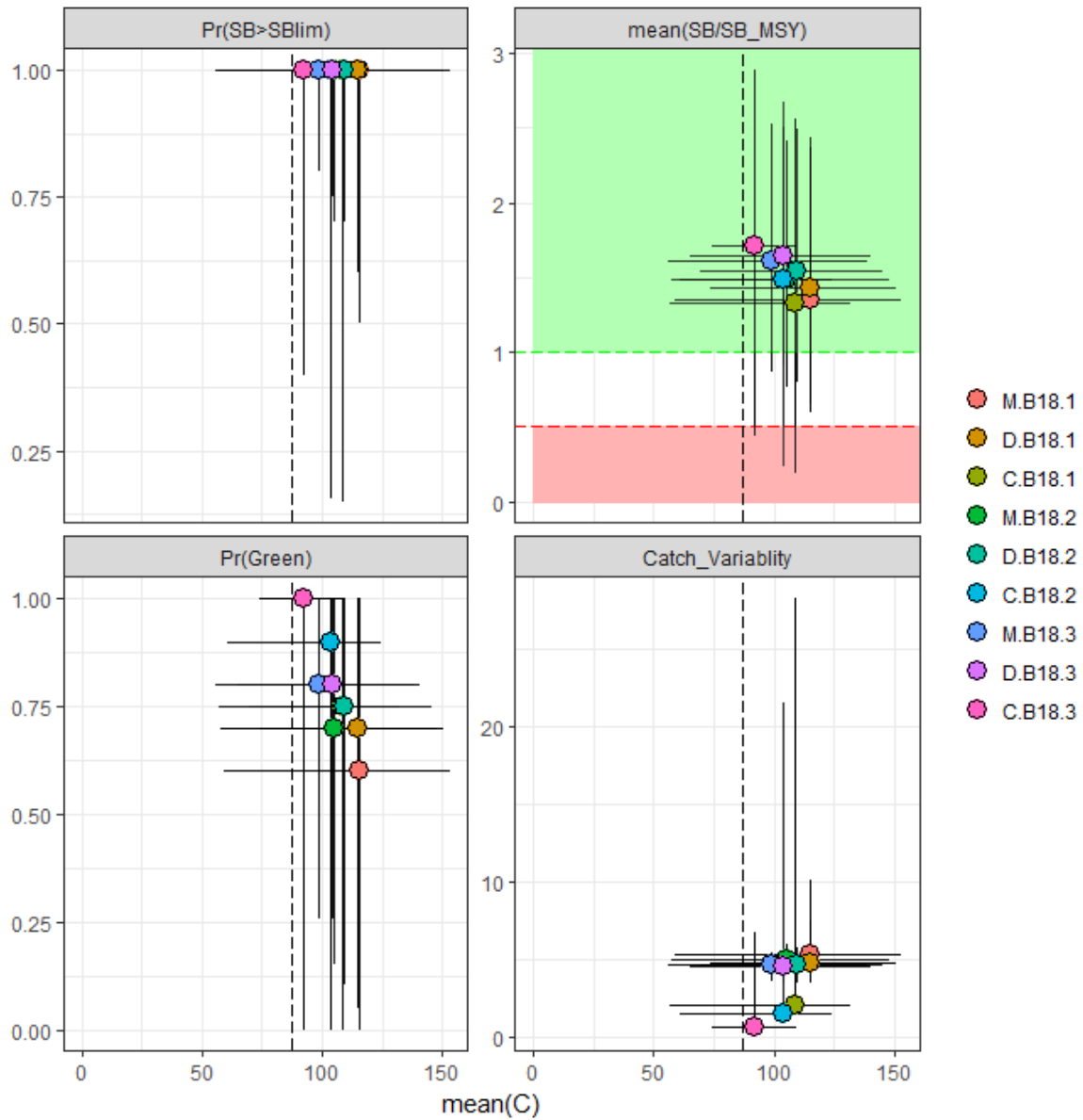
Figure 16. Bigeye robustness case (OMrobB18.5.impErrCV10 - random implementation error) - Trade-off plots comparing candidate MPs with respect to catch on the X-axis, and 4 other key performance measures on the Y-axis, each averaged over the period 2019 - 2038. Circle is the median, lines represent 10th-90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB$_{MSY}$ performance measure. The dashed vertical black line is 2016 catch.
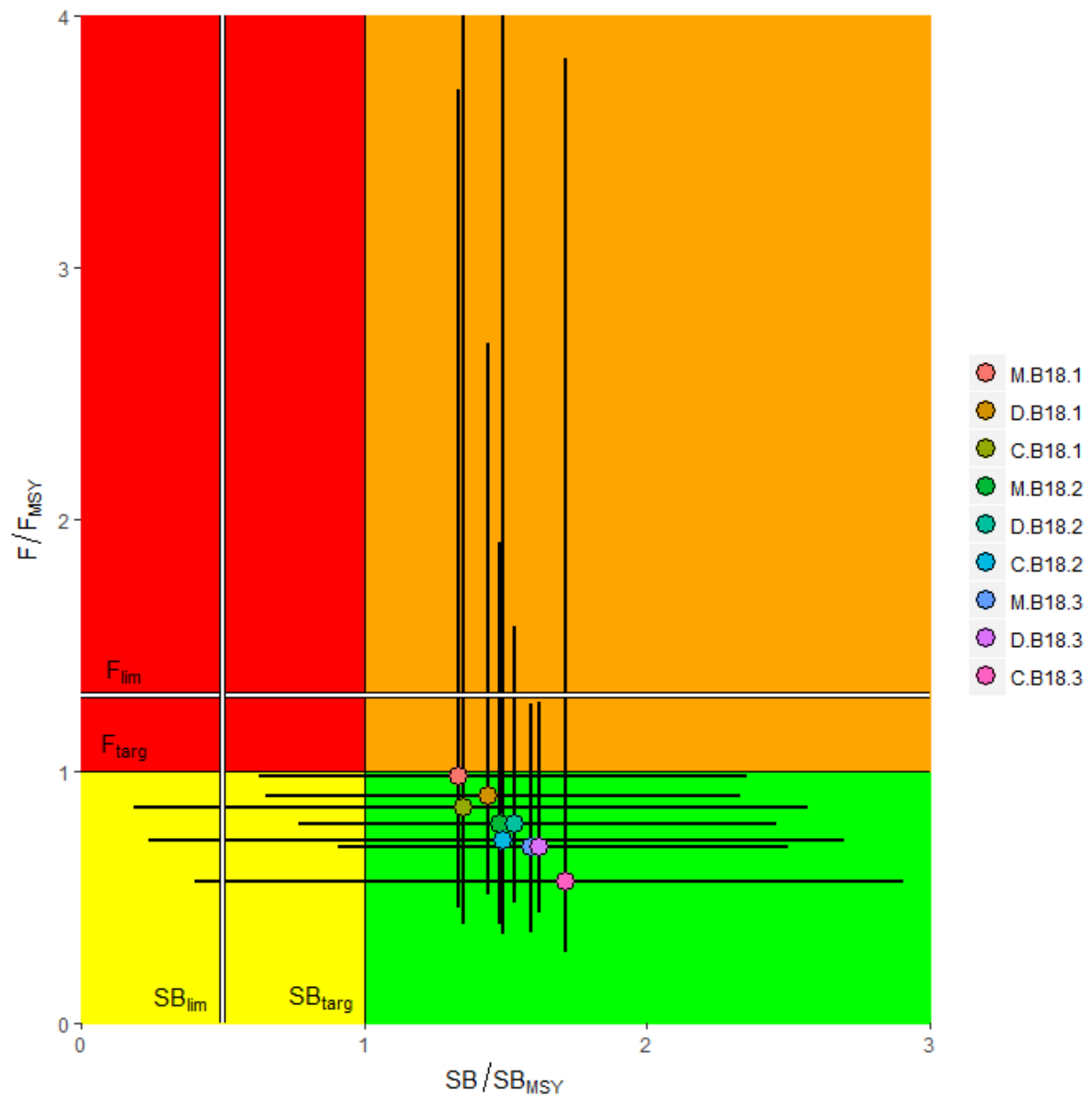
Figure 17. Bigeye robustness case (OMrobB18.5.impErrCV10 - random implementation error) - Kobe plot comparing candidate MPs on the basis of the expected 20 year average (2019-2038) performance. Circle is the median, lines represent 10th-90th percentiles.
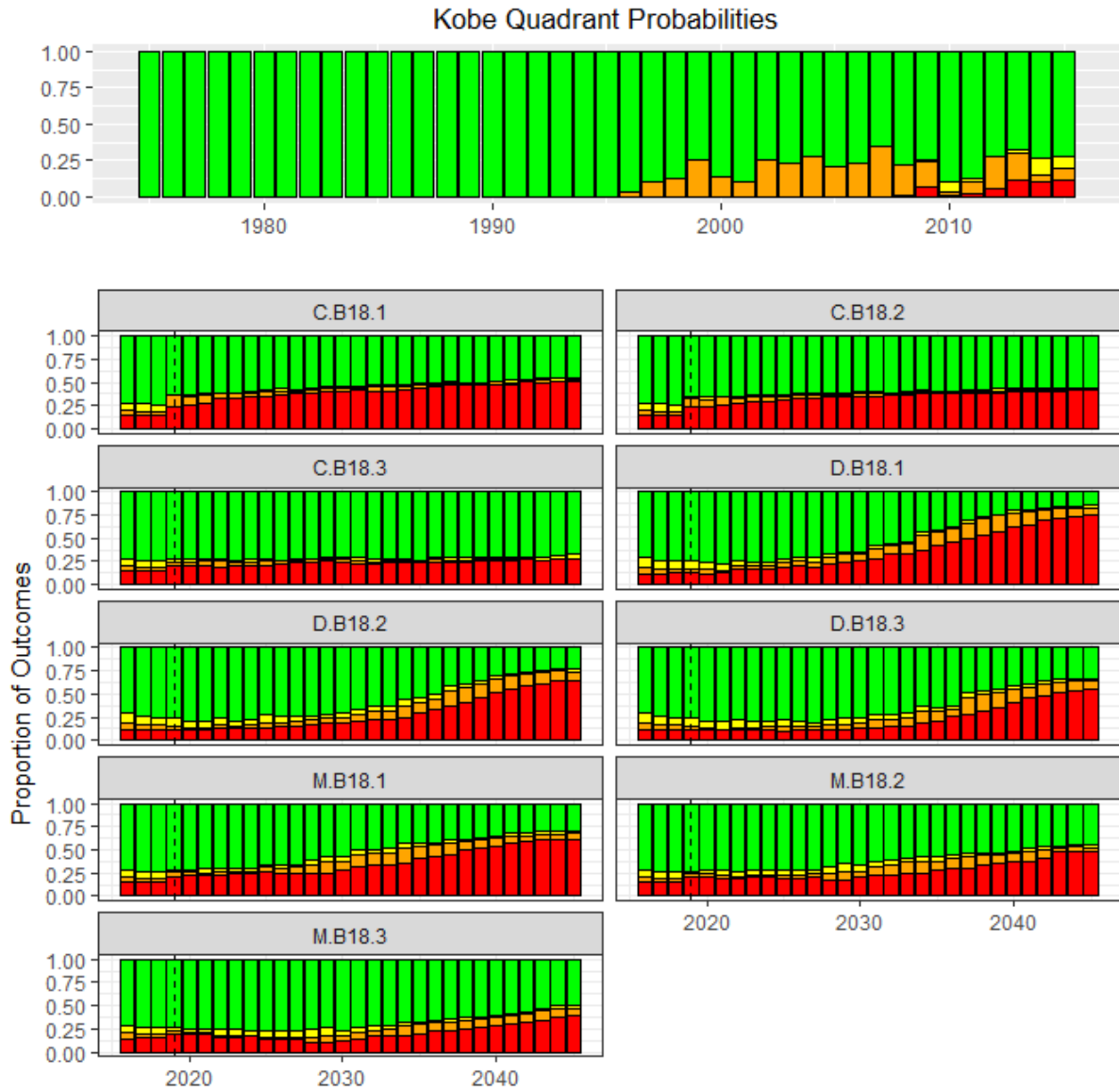
Figure 18. Bigeye robustness case (OMrobB18.5.impErrCV10 - random implementation error) - Proportion of simulations in each of the Kobe quadrants over time for each of the candidate MPs. Historical estimates are included in the top panel. The lower panels are projections, with the first MP application indicated by the broken vertical line (2019).
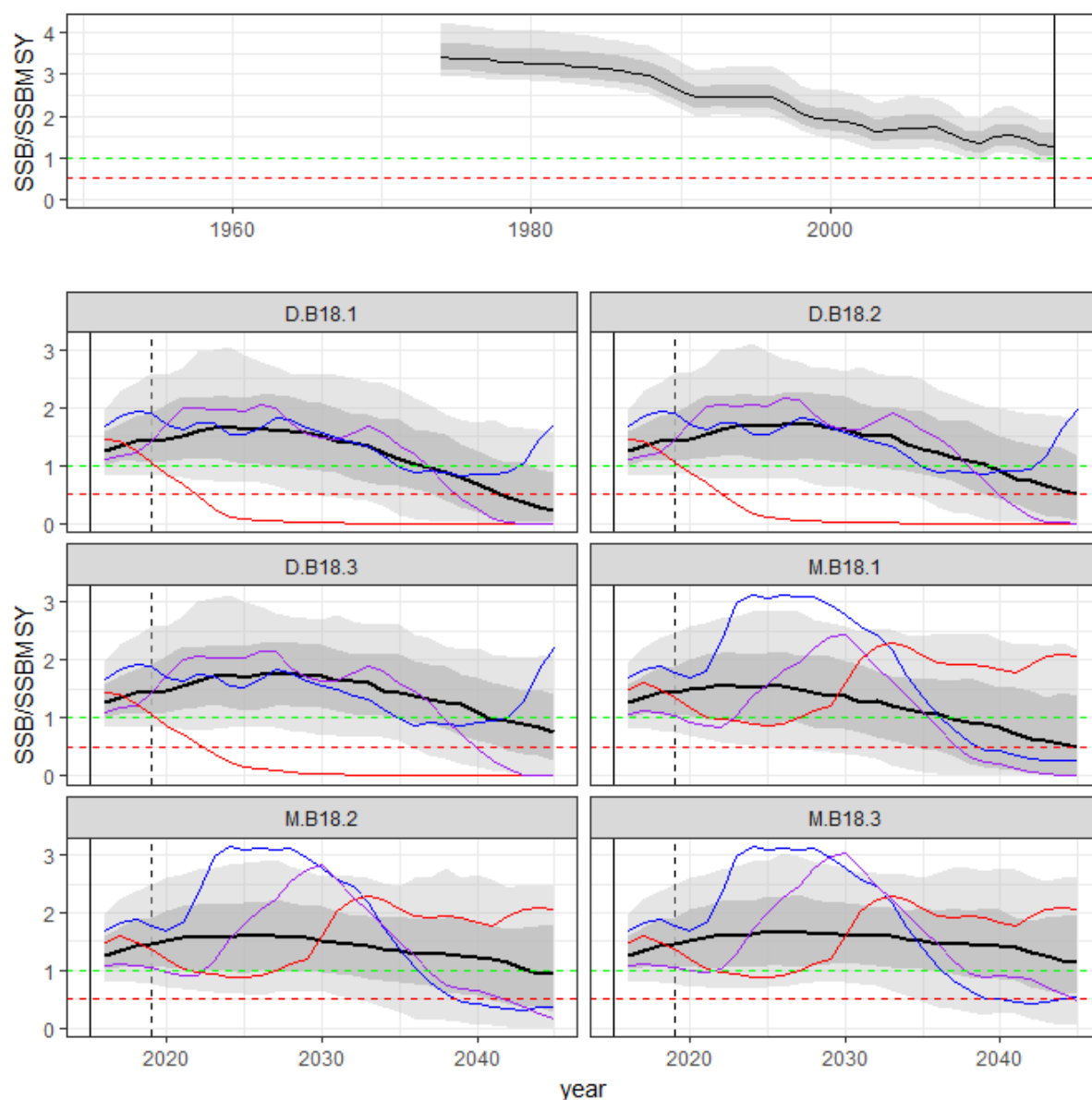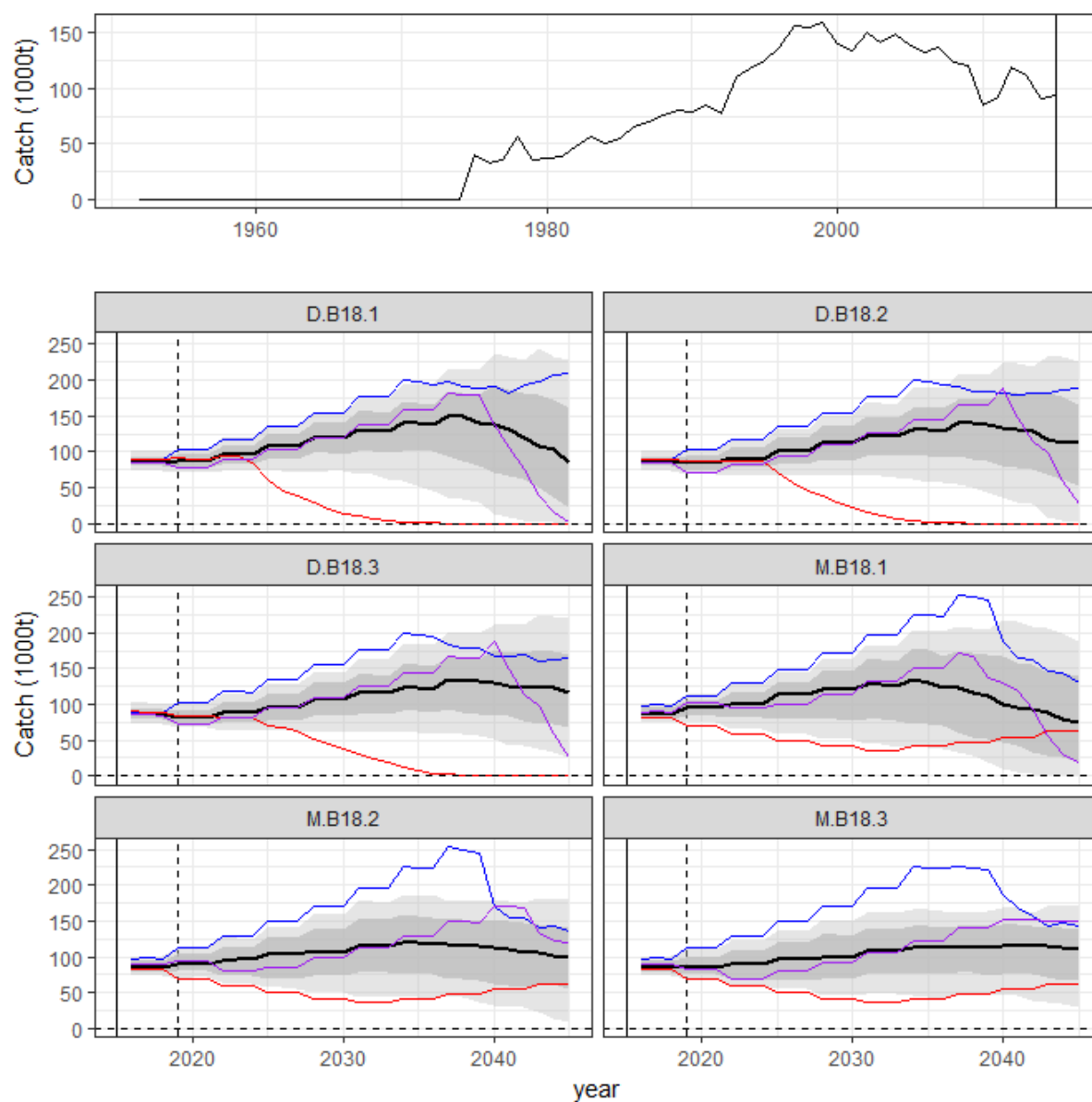
Figure 19. Bigeye robustness case (OMrobB18.5.impErrCV10 - random implementation error) - Time series of spawning stock size for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
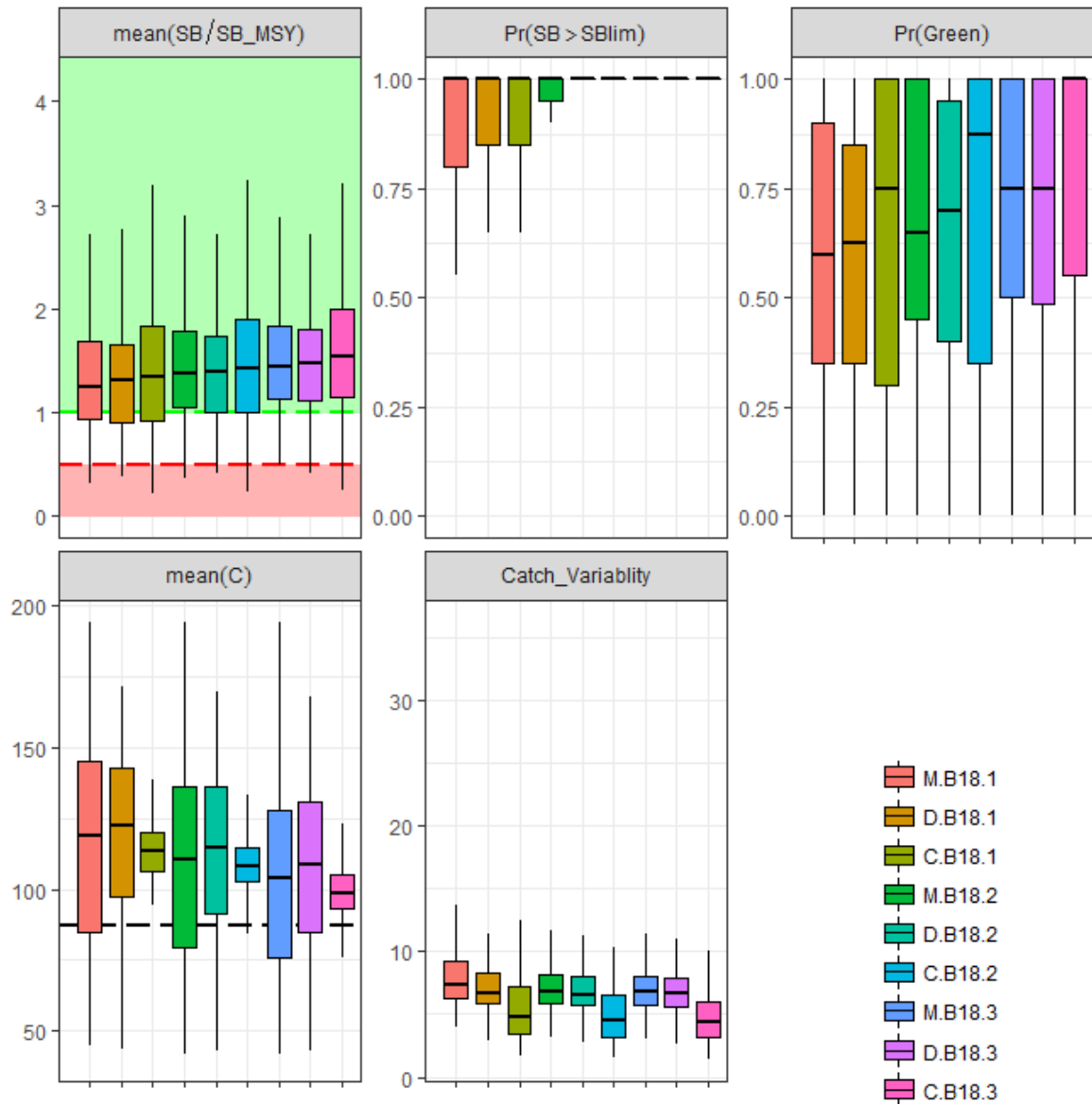
Figure 20. Bigeye robustness case (OMrobB18.5.impErrCV10 - random implementation error) - Time series of fishing intensity (Upper bound truncated at F = 3) for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.

Figure 21. Bigeye robustness case (OMrobB18.5.impErrCV10 - random implementation error) - Time series of catch for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. The broken black horizontal line represents recent (2016) catch. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
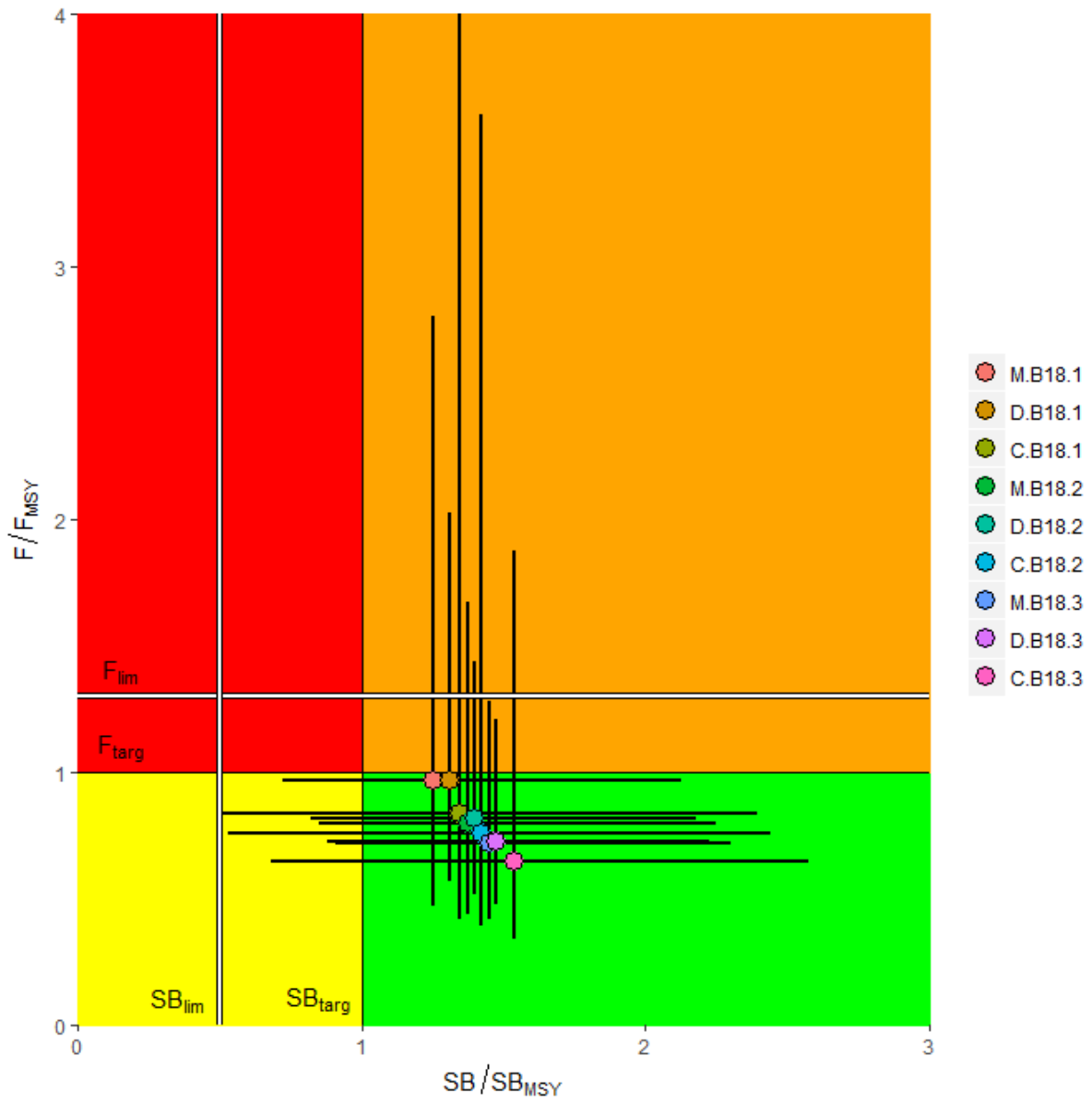
Figure 22. Bigeye robustness case (OMrobB18.5.impErrUnder - undercatch implementation error) - Boxplots comparing candidate MPs with respect to key performance measures averaged over the period 2019 - 2038. Horizontal line is the median, boxes represent 25th - 75th percentiles, thin lines represent 10th - 90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB$_{MSY}$ performance measure. The horizontal dashed black line is 2016 catch.
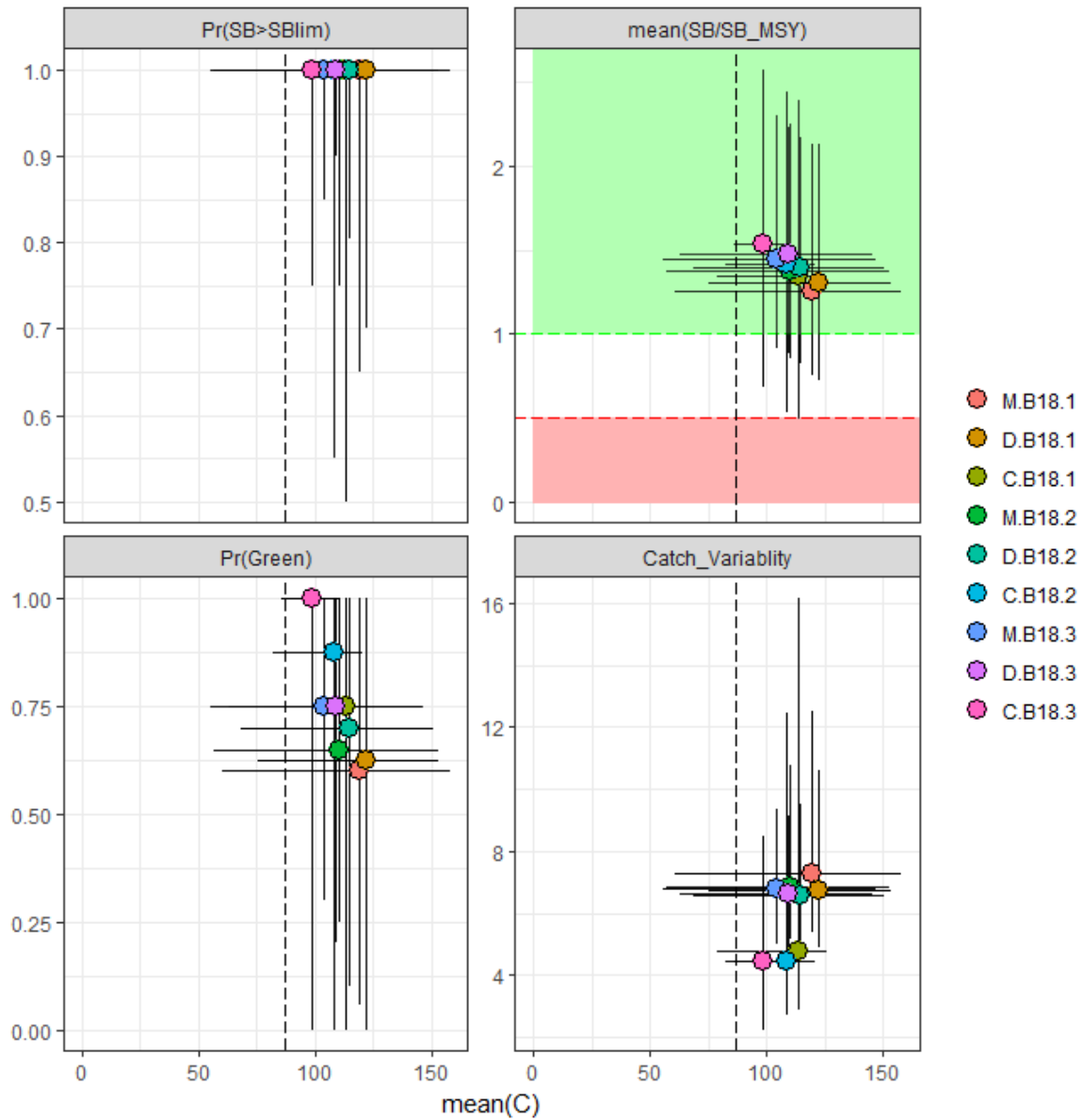
Figure 23. Bigeye robustness case (OMrobB18.5.impErrUnder - undercatch implementation error) - Trade-off plots comparing candidate MPs with respect to catch on the X-axis, and 4 other key performance measures on the Y-axis, each averaged over the period 2019 - 2038. Circle is the median, lines represent 10th-90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB$_{MSY}$ performance measure. The dashed vertical black line is 2016 catch.

Figure 24. Bigeye robustness case (OMrobB18.5.impErrUnder - undercatch implementation error) - Kobe plot comparing candidate MPs on the basis of the expected 20 year average (2019-2038) performance. Circle is the median, lines represent 10th-90th percentiles.
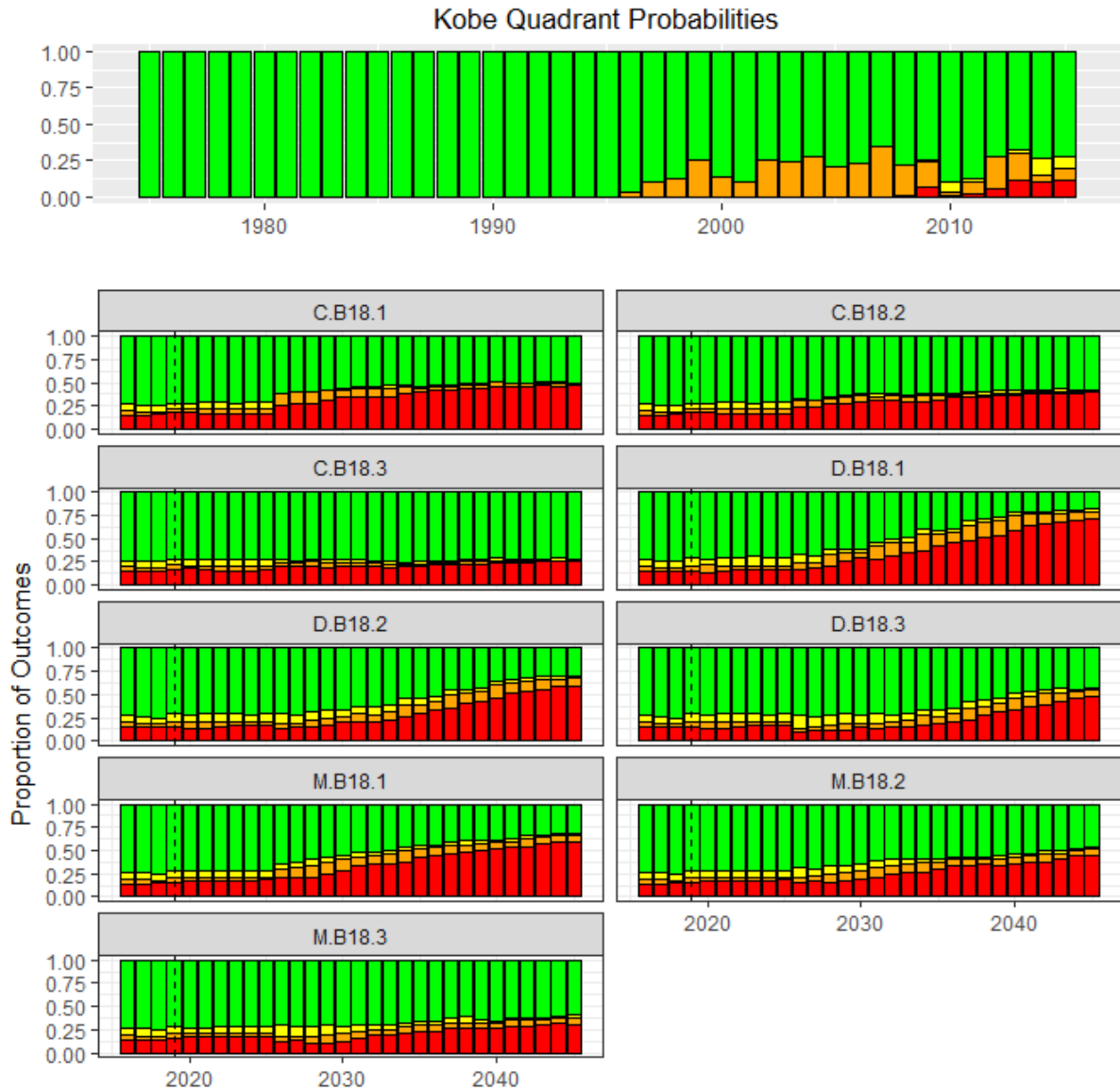
Figure 25.   Bigeye robustness case (OMrobB18.5.impErrUnder - undercatch implementation error) - Proportion of simulations in each of the Kobe quadrants over time for each of the candidate MPs. Historical estimates are included in the top panel. The lower panels are projections, with the first MP application indicated by the broken vertical line (2019).
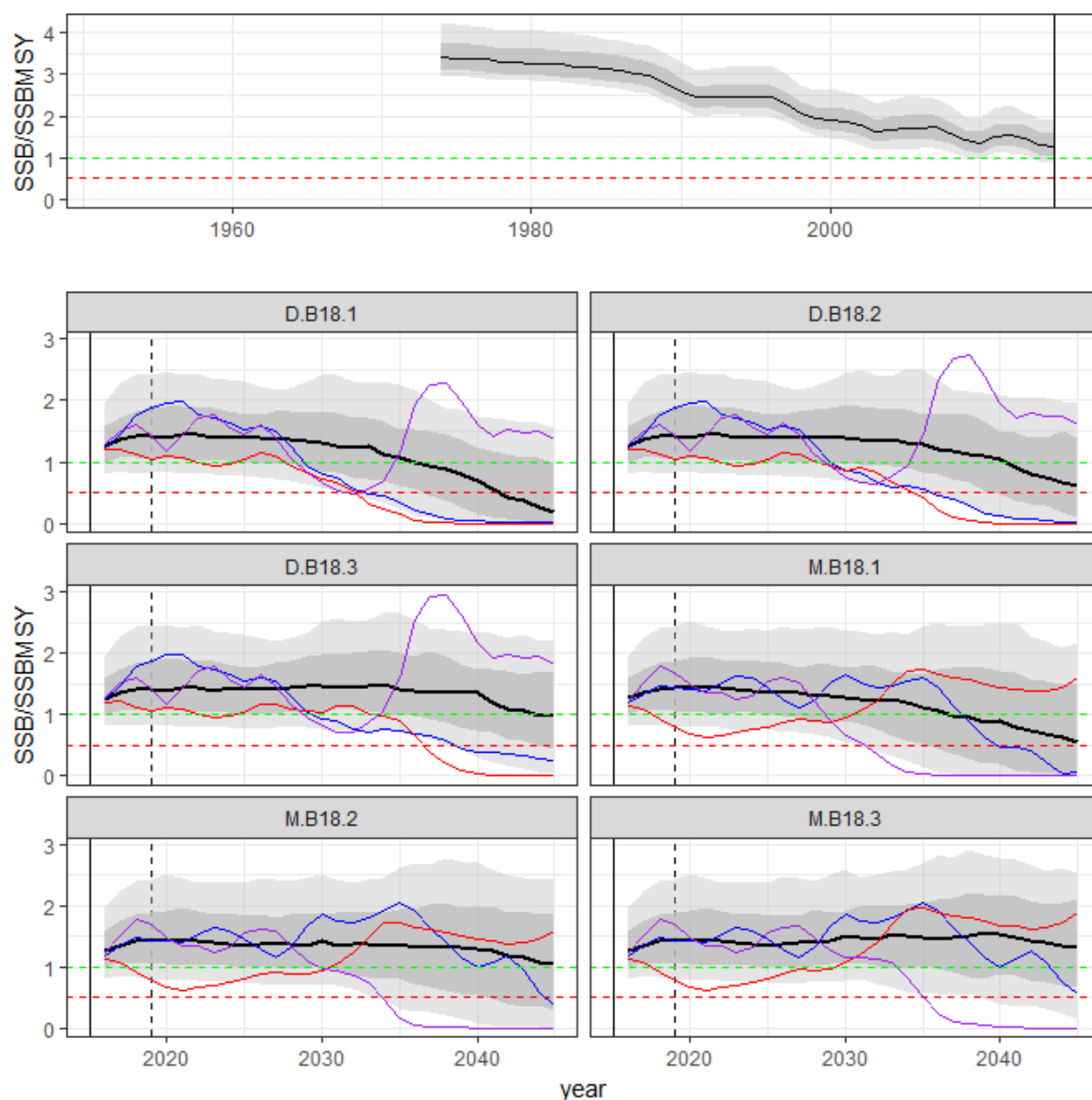
Figure 26. Bigeye robustness case (OMrobB18.5.impErrUnder - undercatch implementation error) - Time series of spawning stock size for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
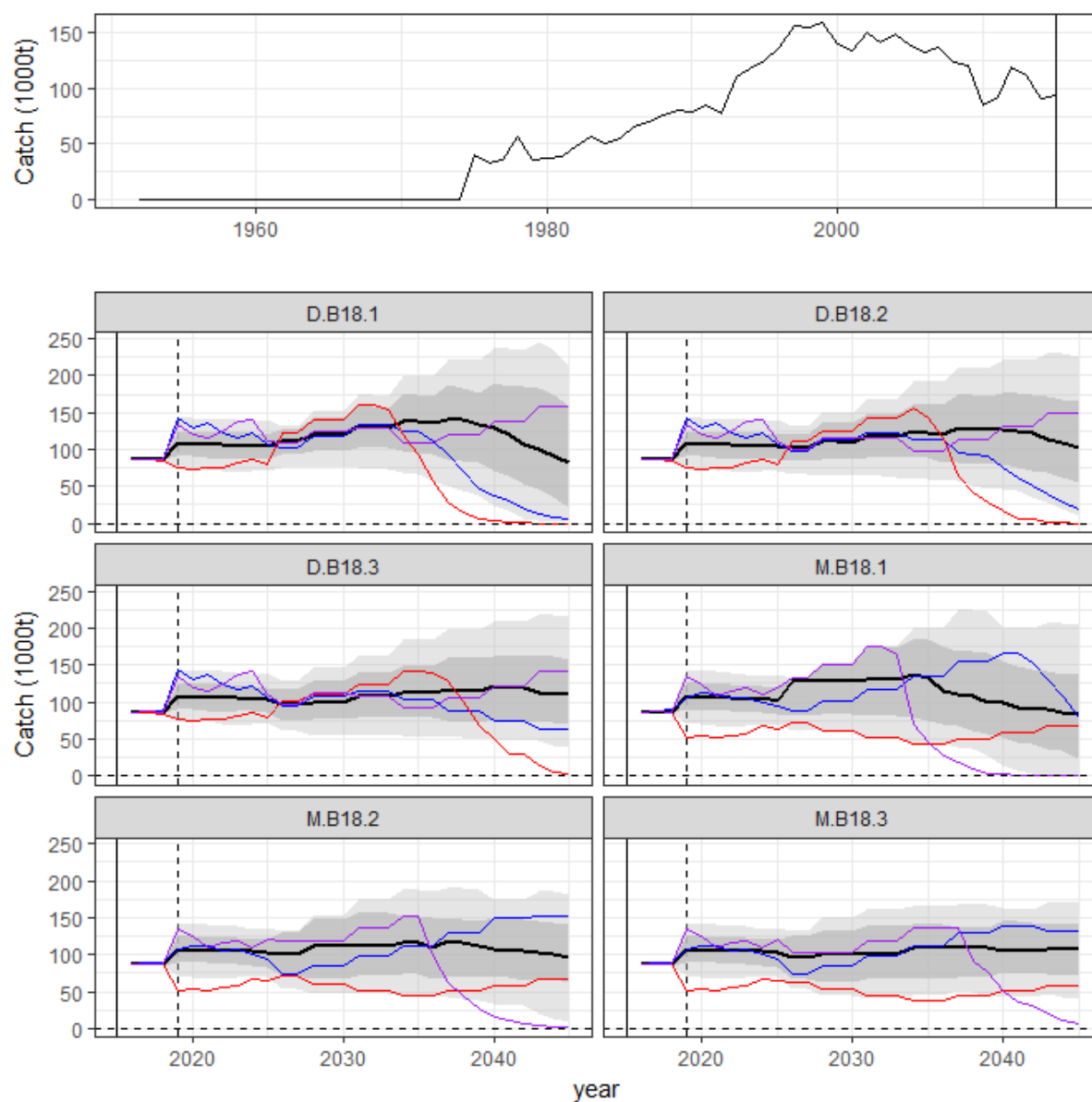
Figure 27. Bigeye robustness case (OMrobB18.5.impErrUnder - undercatch implementation error) - Time series of fishing intensity (Upper bound truncated at F = 3) for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
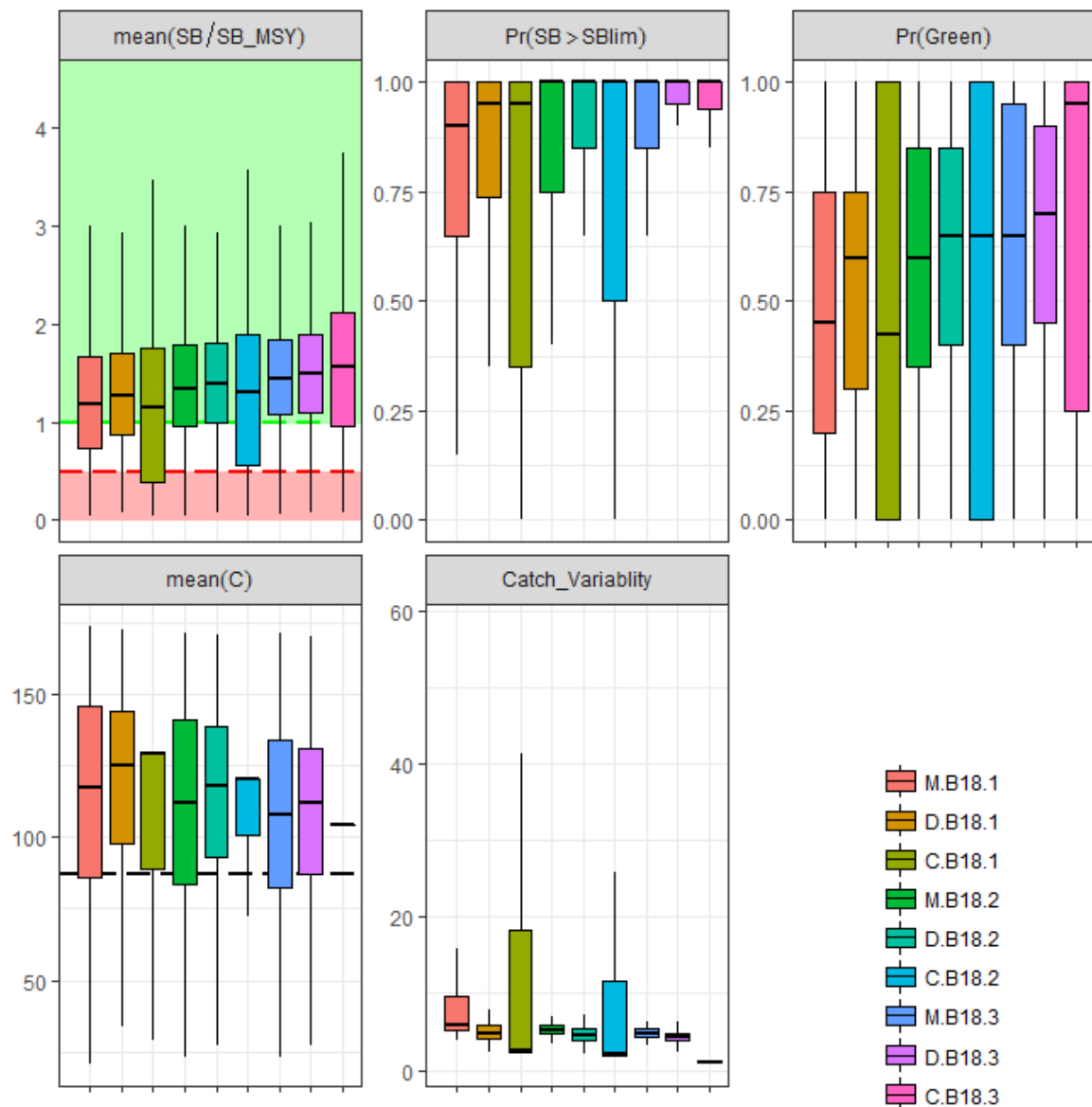
Figure 28. Bigeye robustness case (OMrobB18.5.impErrUnder - undercatch implementation error) - Time series of catch for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. The broken black horizontal line represents recent (2016) catch. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.

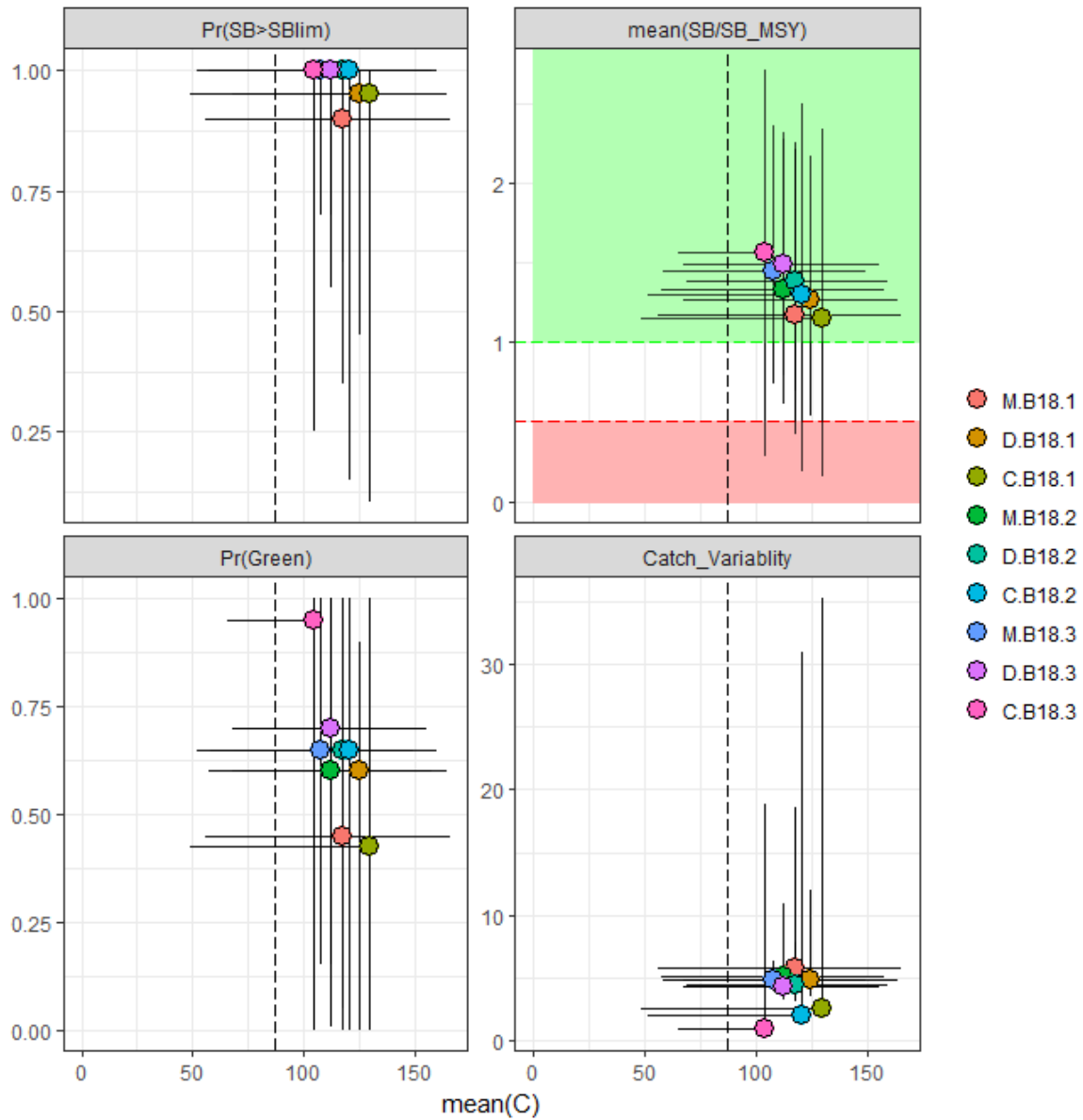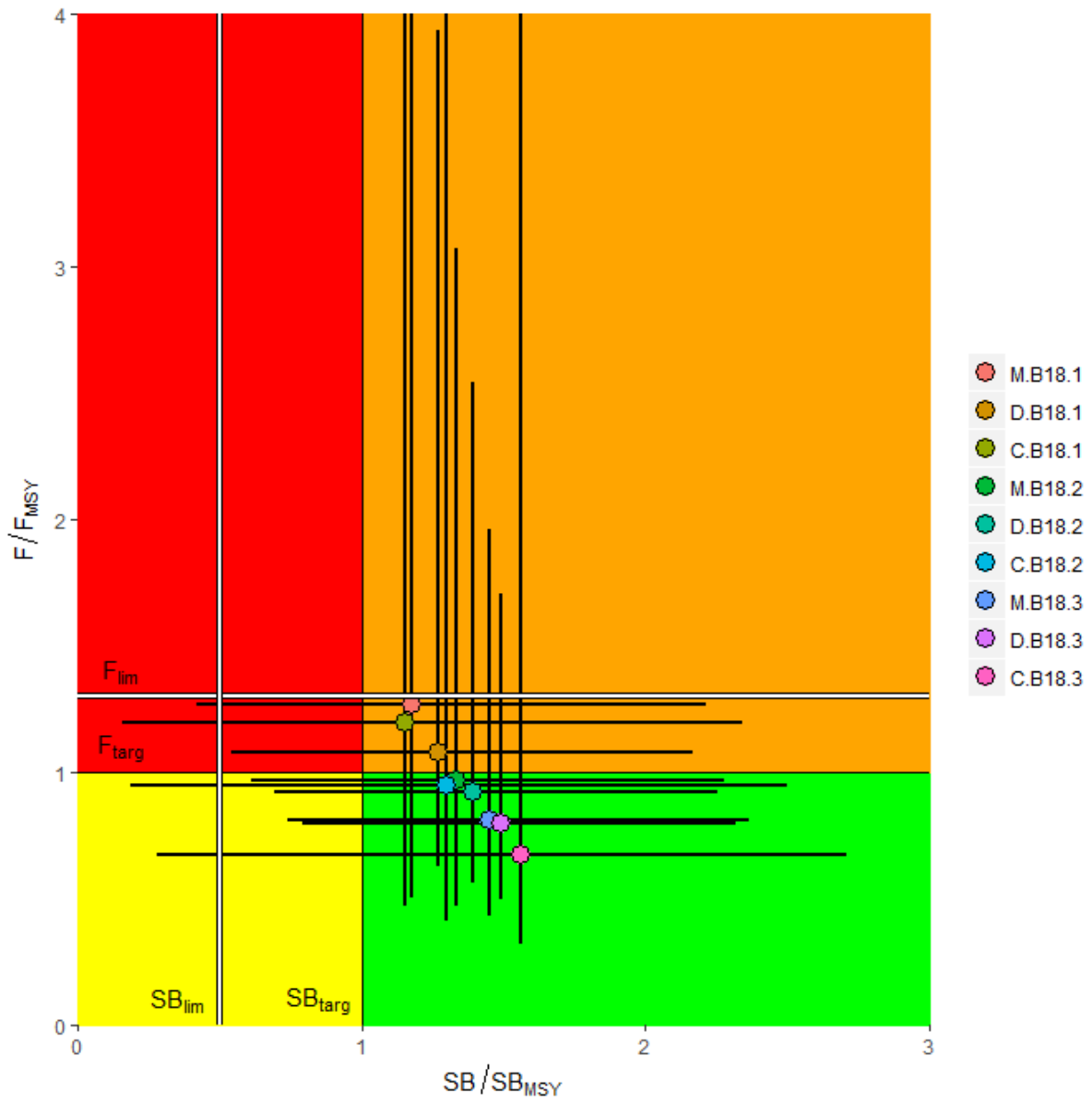*Figure 29. Bigeye robustness case (OMrobB18.5.impErrOver - overcatch implementation error) - Boxplots comparing candidate MPs with respect to key performance measures averaged over the period 2019 - 2038. Horizontal line is the median, boxes represent 25th - 75th percentiles, thin lines represent 10th - 90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB$_{MSY}$ performance measure. The horizontal dashed black line is 2016 catch.*

Figure 30. Bigeye robustness case (OMrobB18.5.impErrOver -overcatch implementation error) - Trade-off plots comparing candidate MPs with respect to catch on the X-axis, and 4 other key performance measures on the Y-axis, each averaged over the period 2019 - 2038. Circle is the median, lines represent 10th-90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB_{MSY} performance measure. The dashed vertical black line is 2016 catch.

Figure 31. Bigeye robustness case (OMrobB18.5.impErrOver - overcatch implementation error) - Kobe plot comparing candidate MPs on the basis of the expected 20 year average (2019-2038) performance. Circle is the median, lines represent 10th-90th percentiles.
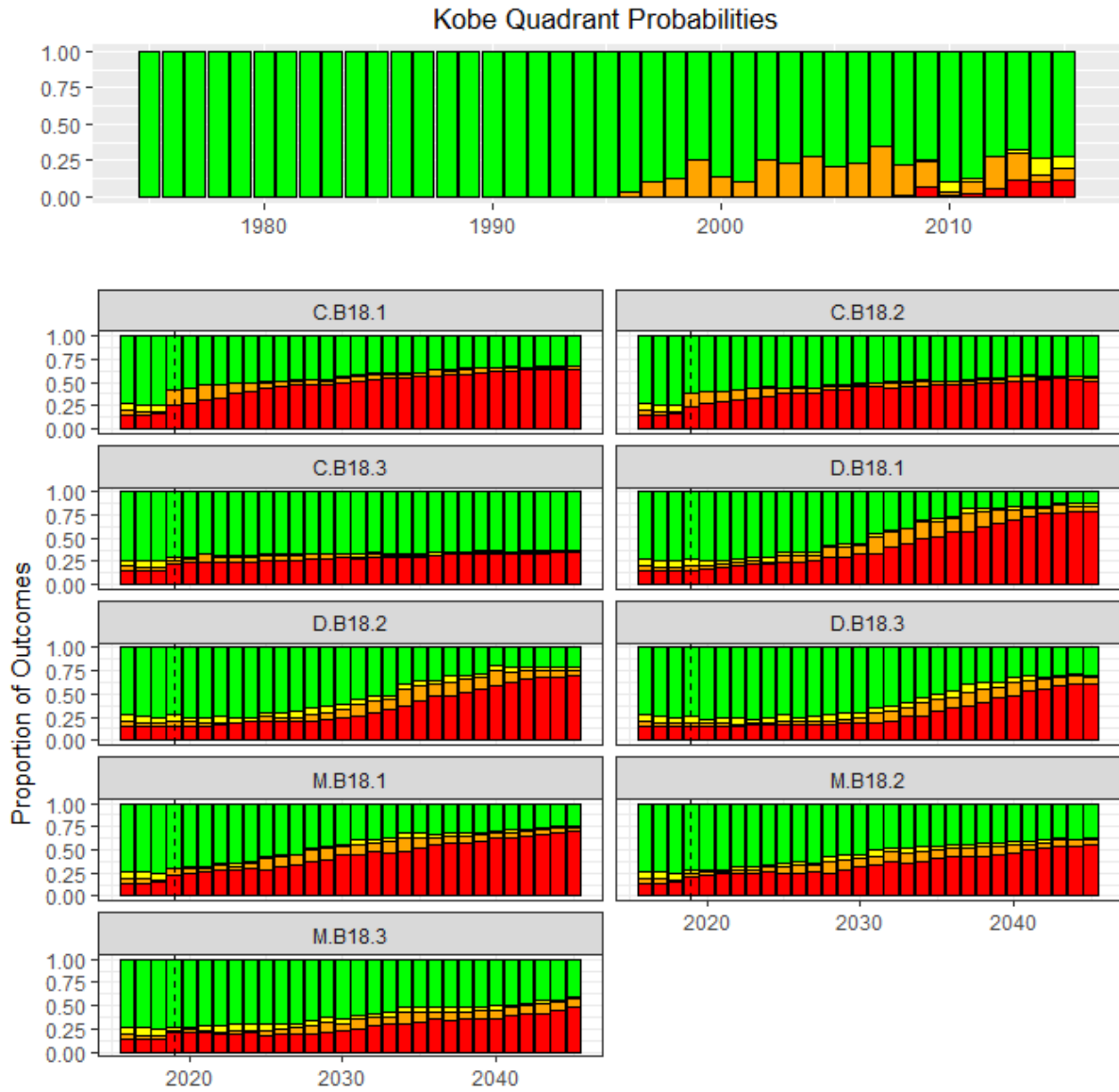
Figure 32. Bigeye robustness case (OMrobB18.5.impErrOver - overcatch implementation error) - Proportion of simulations in each of the Kobe quadrants over time for each of the candidate MPs. Historical estimates are included in the top panel. The lower panels are projections, with the first MP application indicated by the broken vertical line (2019).
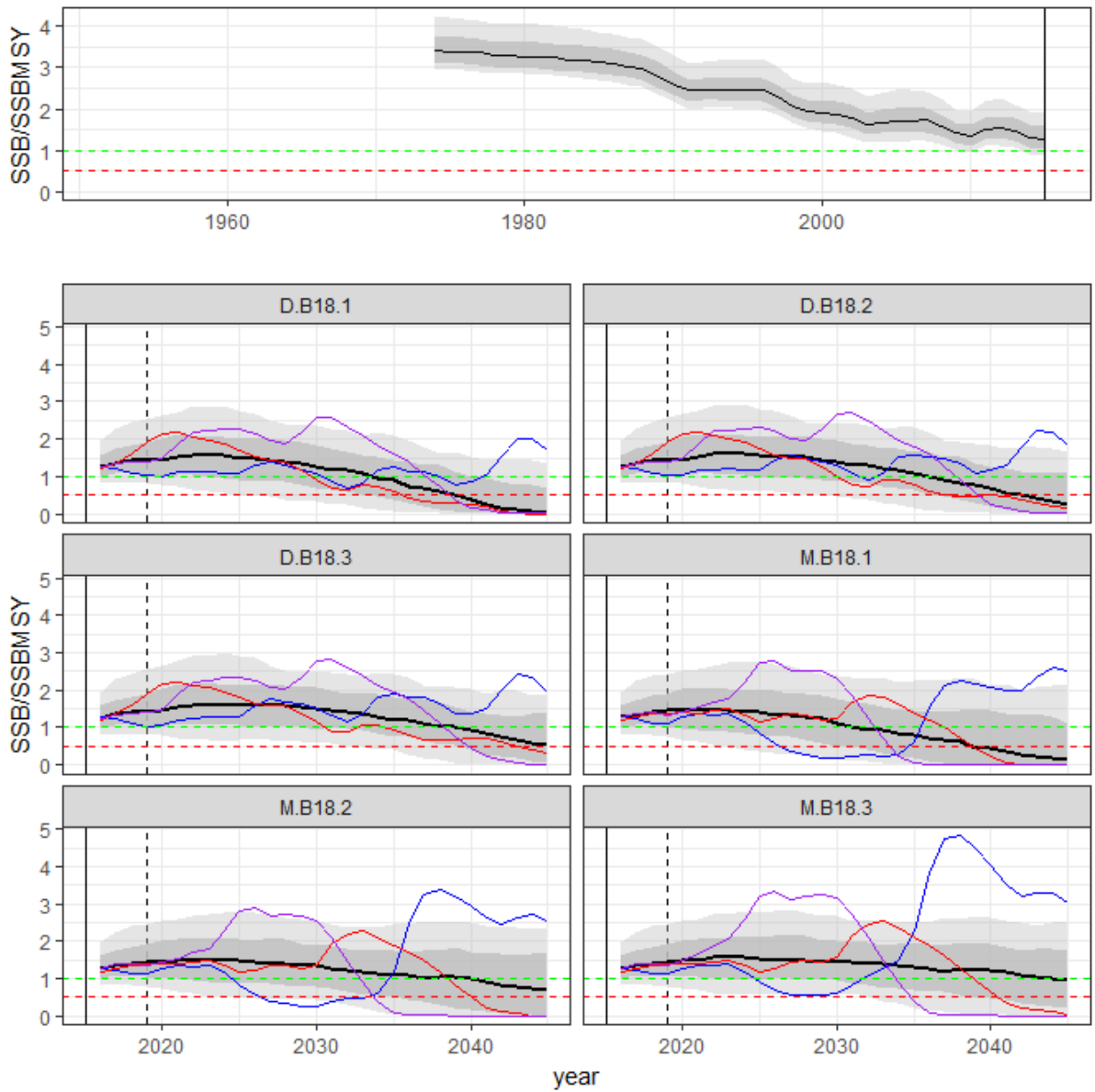
Figure 33. Bigeye robustness case (OMrobB18.5.impErrOver - overcatch implementation error) - Time series of spawning stock size for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
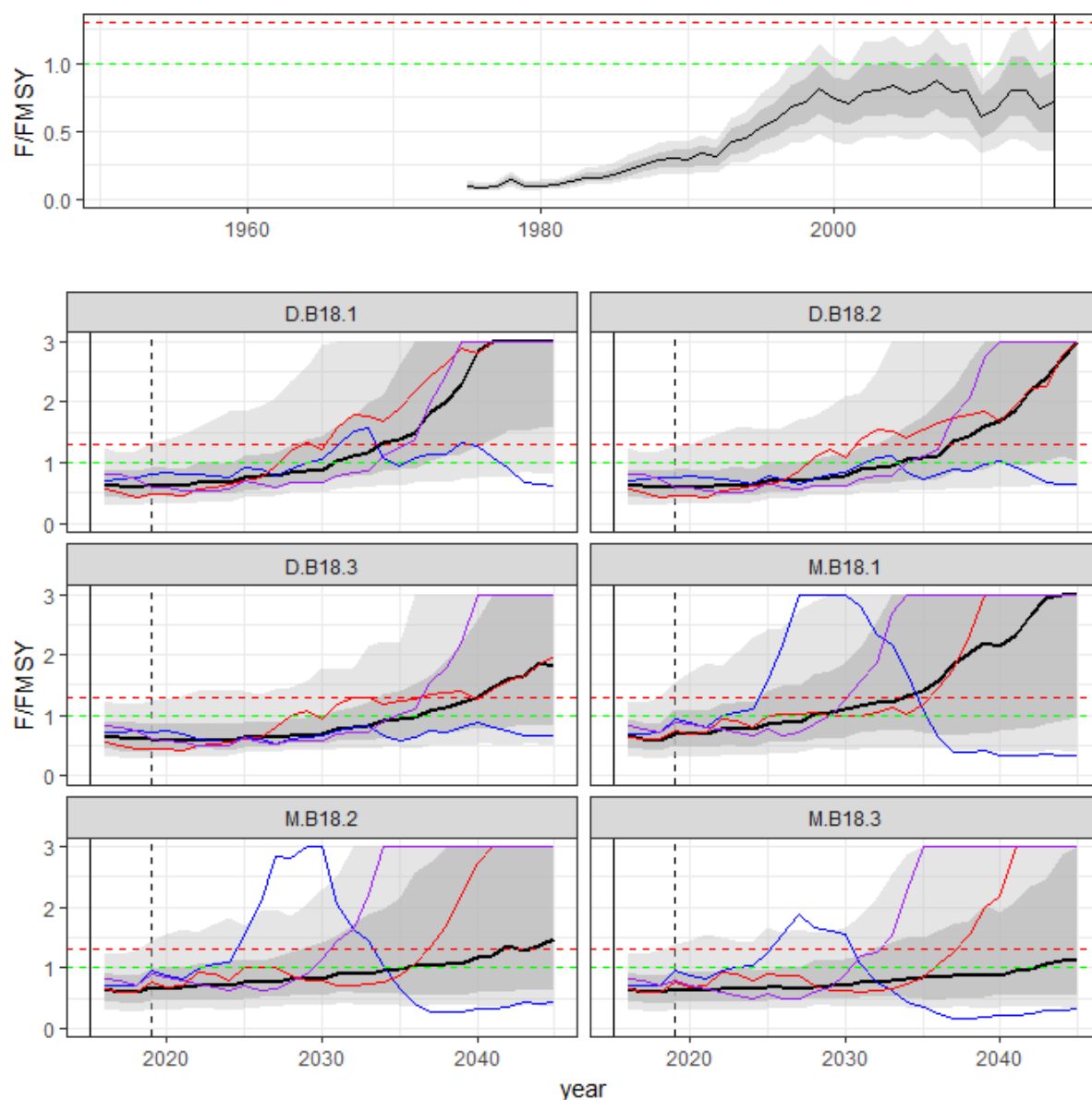
Figure 34. Bigeye robustness case (OMrobB18.5.impErrOver - overcatch implementation error) - Time series of fishing intensity (Upper bound truncated at F = 3) for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
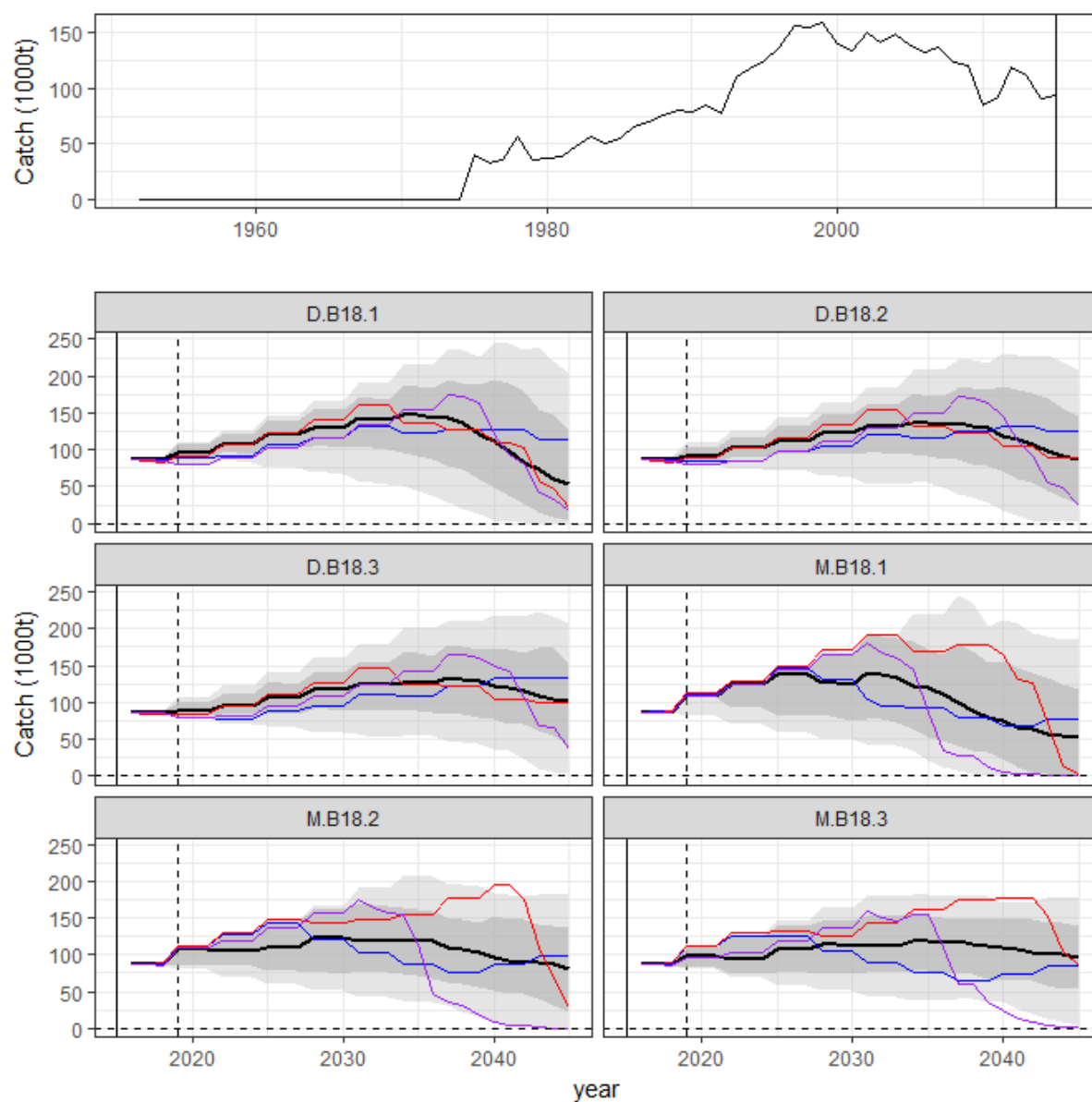
Figure 35. Bigeye robustness case (OMrobB18.5.impErrOver - overcatch implementation error) - Time series of catch for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. The broken black horizontal line represents recent (2016) catch. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
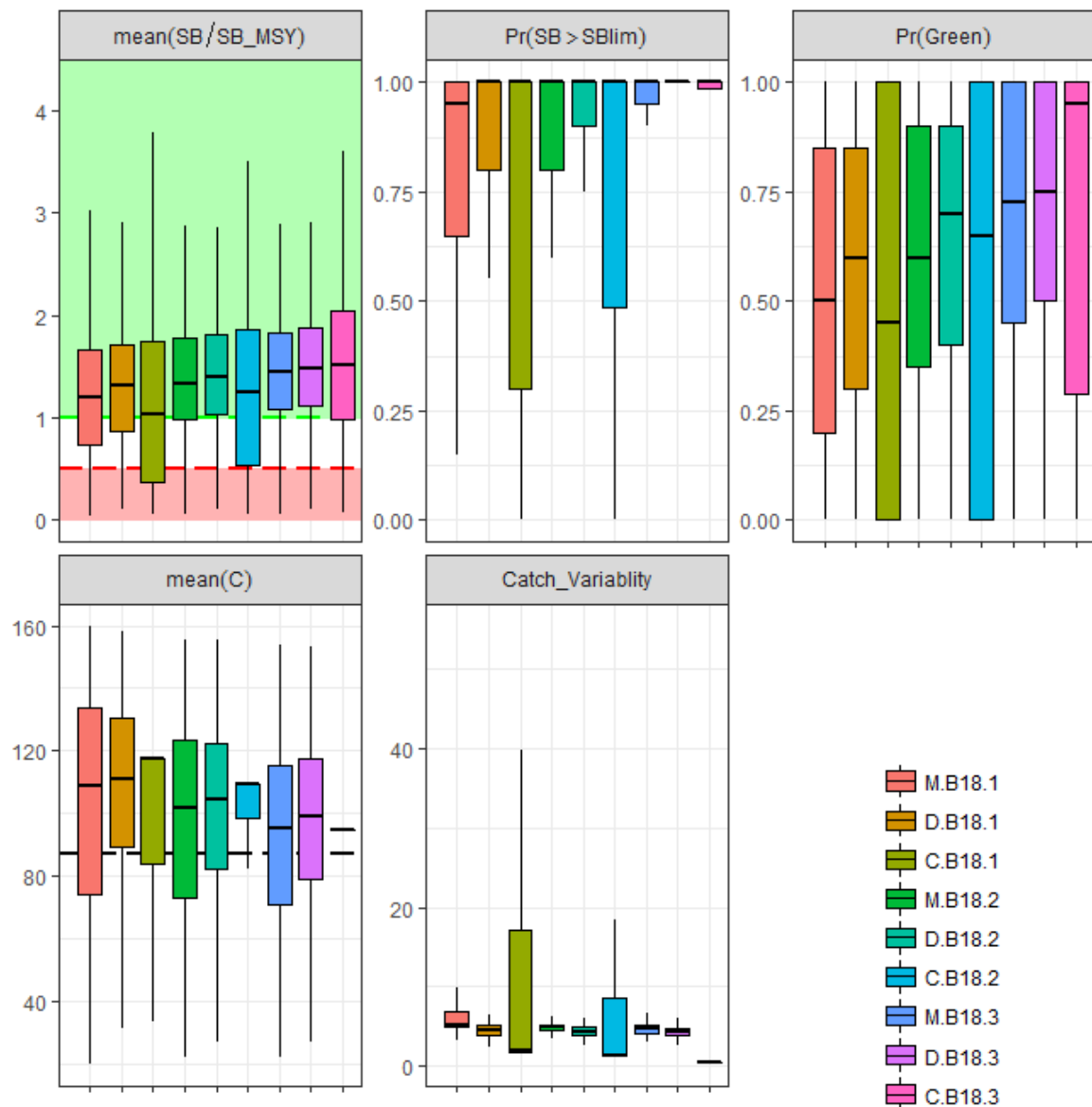
Figure 36. Bigeye robustness case (OMrobB18.5.recShock - 8 quarter recruitment failure) - Boxplots comparing candidate MPs with respect to key performance measures averaged over the period 2019 - 2038. Horizontal line is the median, boxes represent 25th - 75th percentiles, thin lines represent 10th - 90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB$_{MSY}$ performance measure. The horizontal dashed black line is 2016 catch.
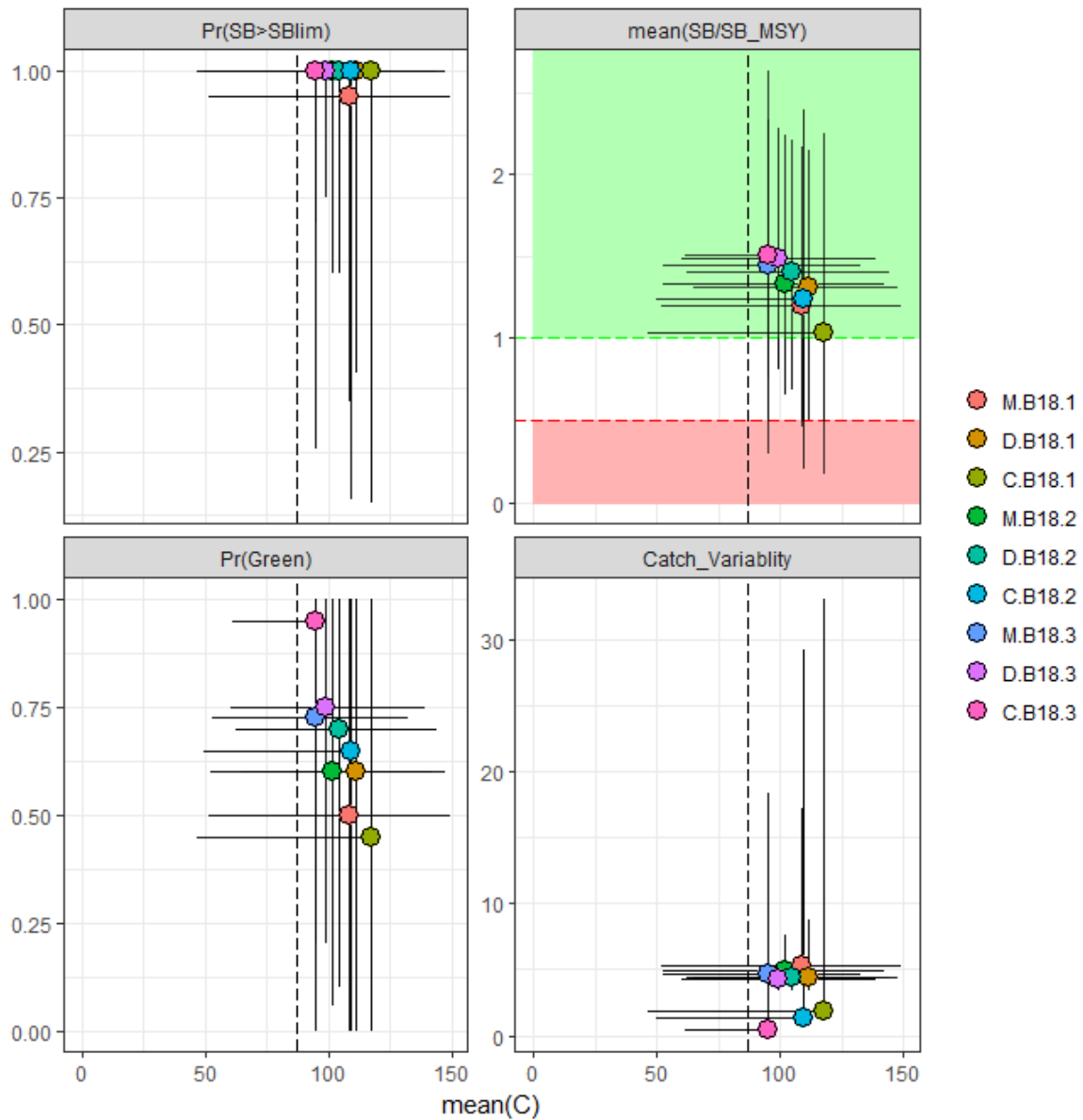
Figure 37. Bigeye robustness case (OMrobB18.5.recShock - 8 quarter recruitment failure) - Trade-off plots comparing candidate MPs with respect to catch on the X-axis, and 4 other key performance measures on the Y-axis, each averaged over the period 2019 - 2038. Circle is the median, lines represent 10th-90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB$_{MSY}$ performance measure. The dashed vertical black line is 2016 catch.
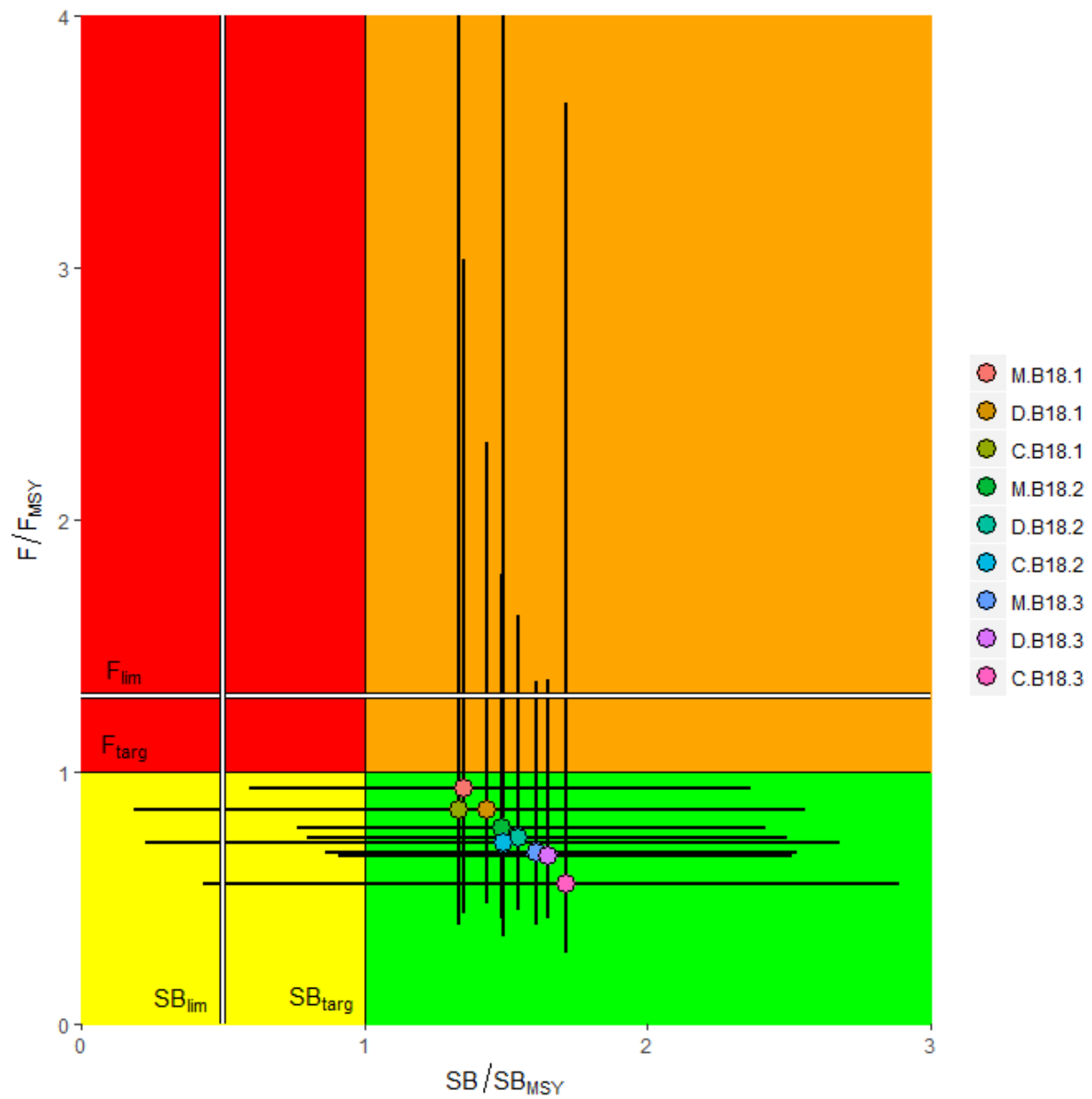
Figure 38. Bigeye robustness case (OMrobB18.5.recShock - 8 quarter recruitment failure) - Kobe plot comparing candidate MPs on the basis of the expected 20 year average (2019-2038) performance. Circle is the median, lines represent 10th-90th percentiles.
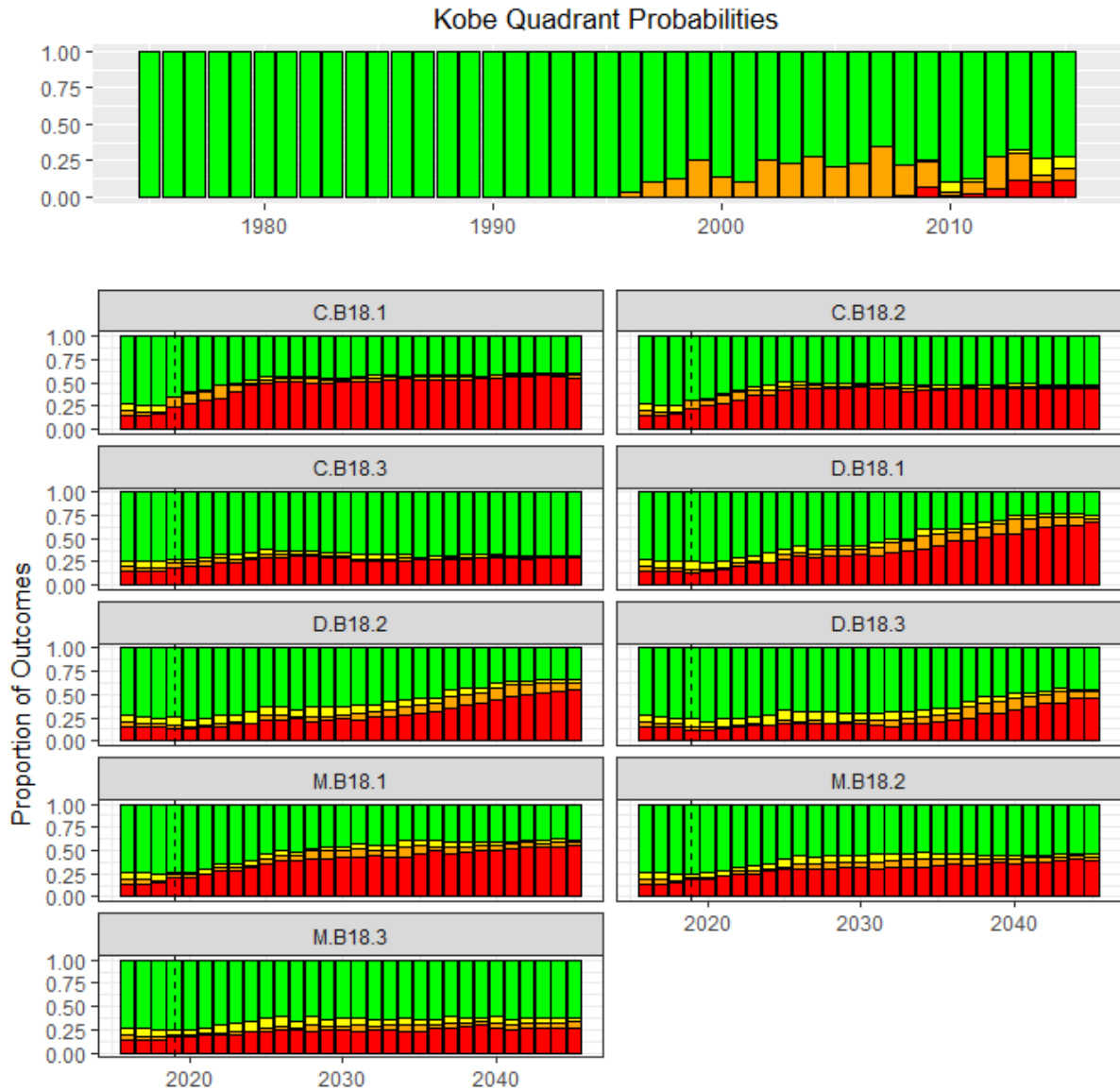
Figure 39. Bigeye robustness case (OMrobB18.5.recShock - 8 quarter recruitment failure) - Proportion of simulations in each of the Kobe quadrants over time for each of the candidate MPs. Historical estimates are included in the top panel. The lower panels are projections, with the first MP application indicated by the broken vertical line (2019).
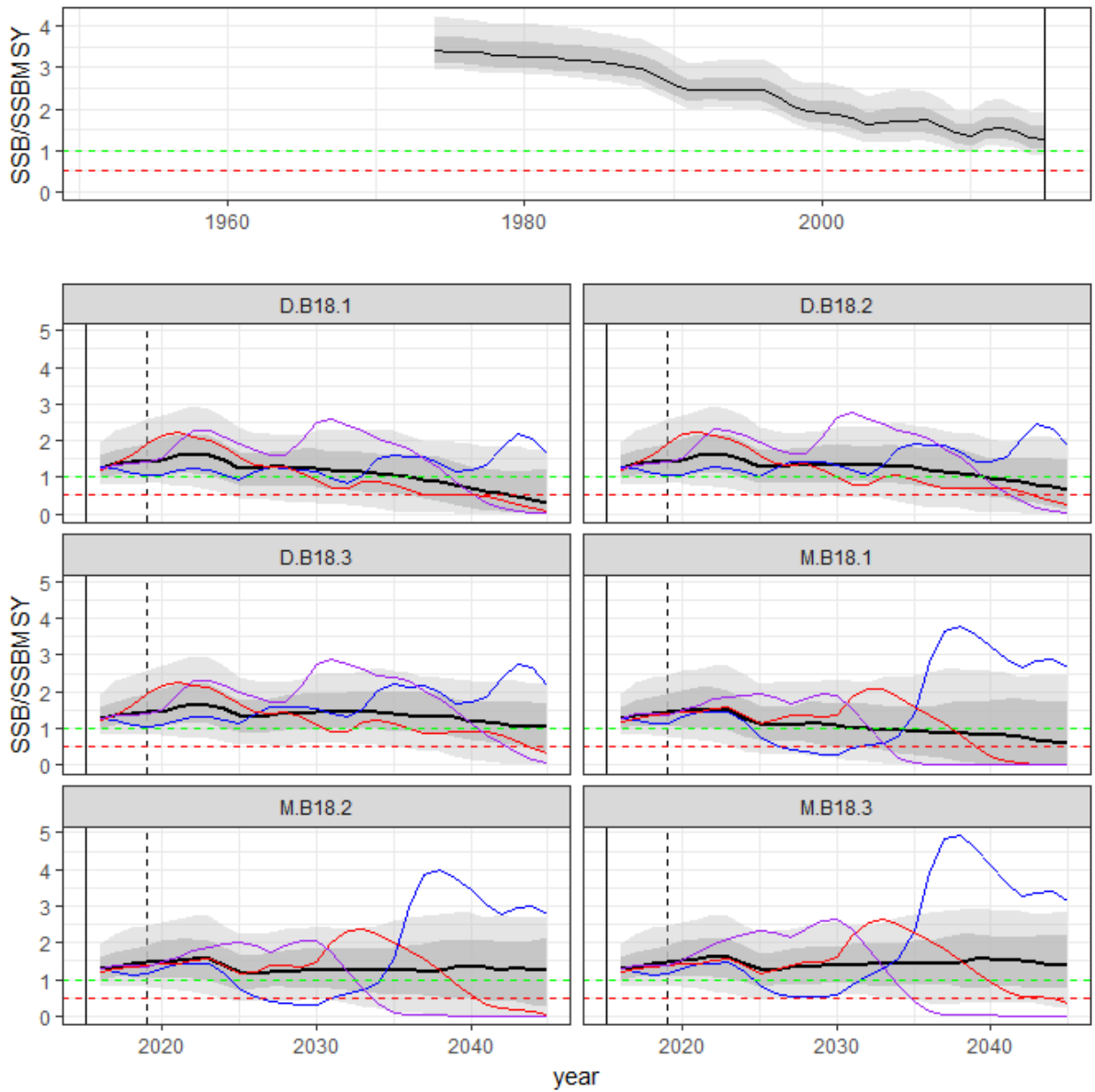
Figure 40. Bigeye robustness case (OMrobB18.5.recShock - 8 quarter recruitment failure) - Time series of spawning stock size for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year

Figure 41. Bigeye robustness case (OMrobB18.5.recShock - 8 quarter recruitment failure) - Time series of fishing intensity (Upper bound truncated at F = 3) for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The 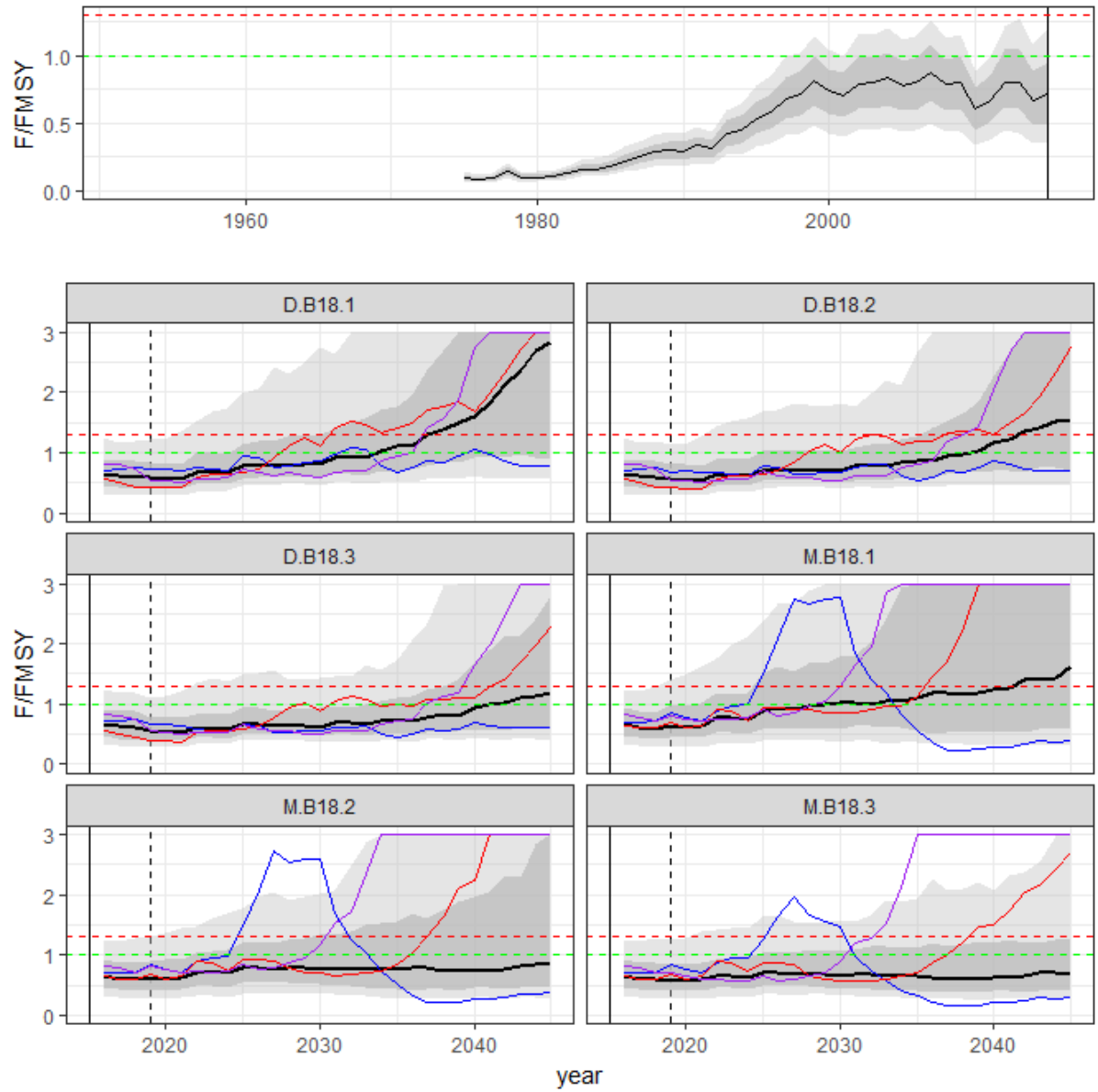broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
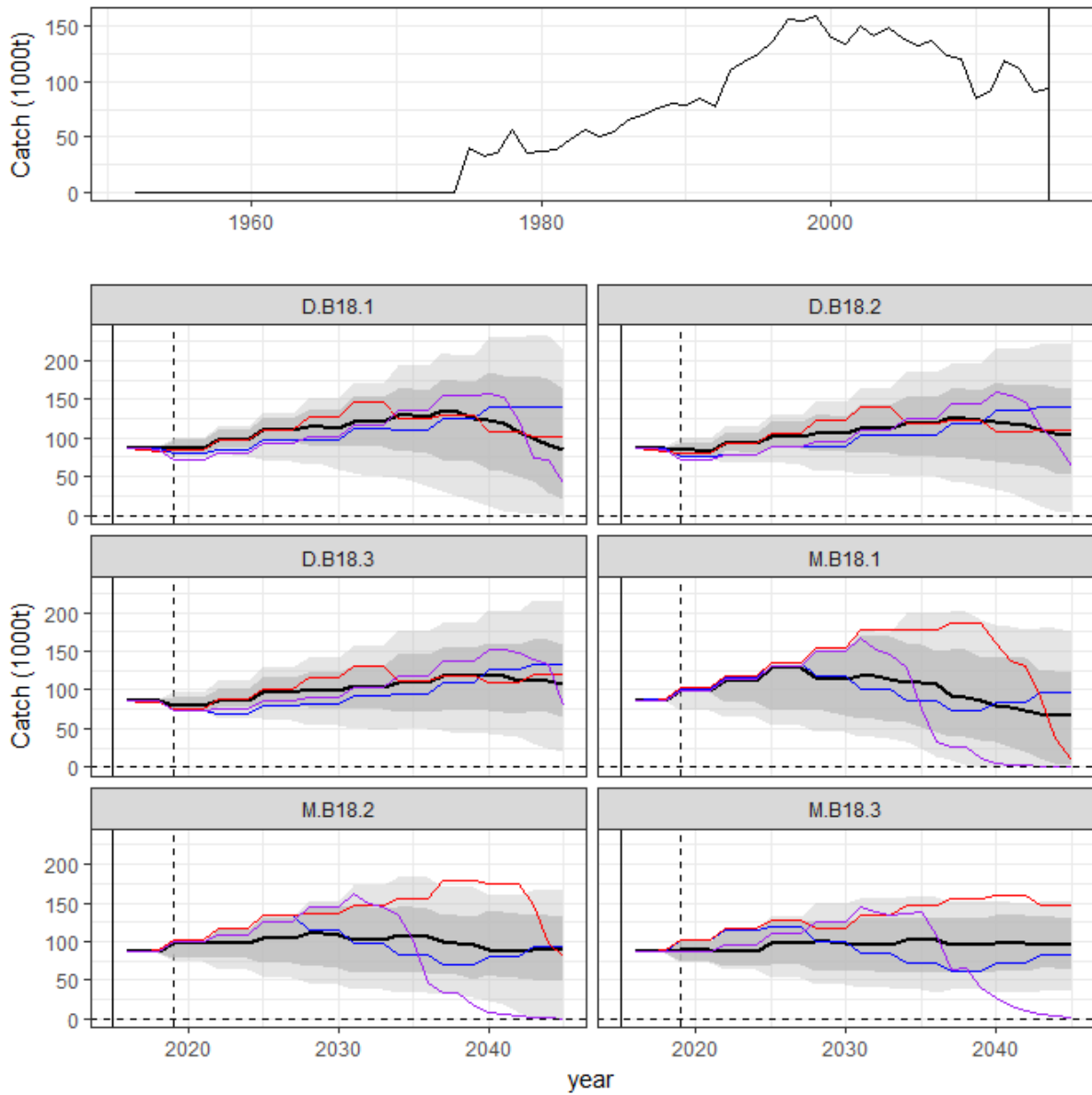
Figure 42. Bigeye robustness case (OMrobB18.5.recShock - 8 quarter recruitment failure) - Time series of catch for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. The broken black horizontal line represents recent (2016) catch. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
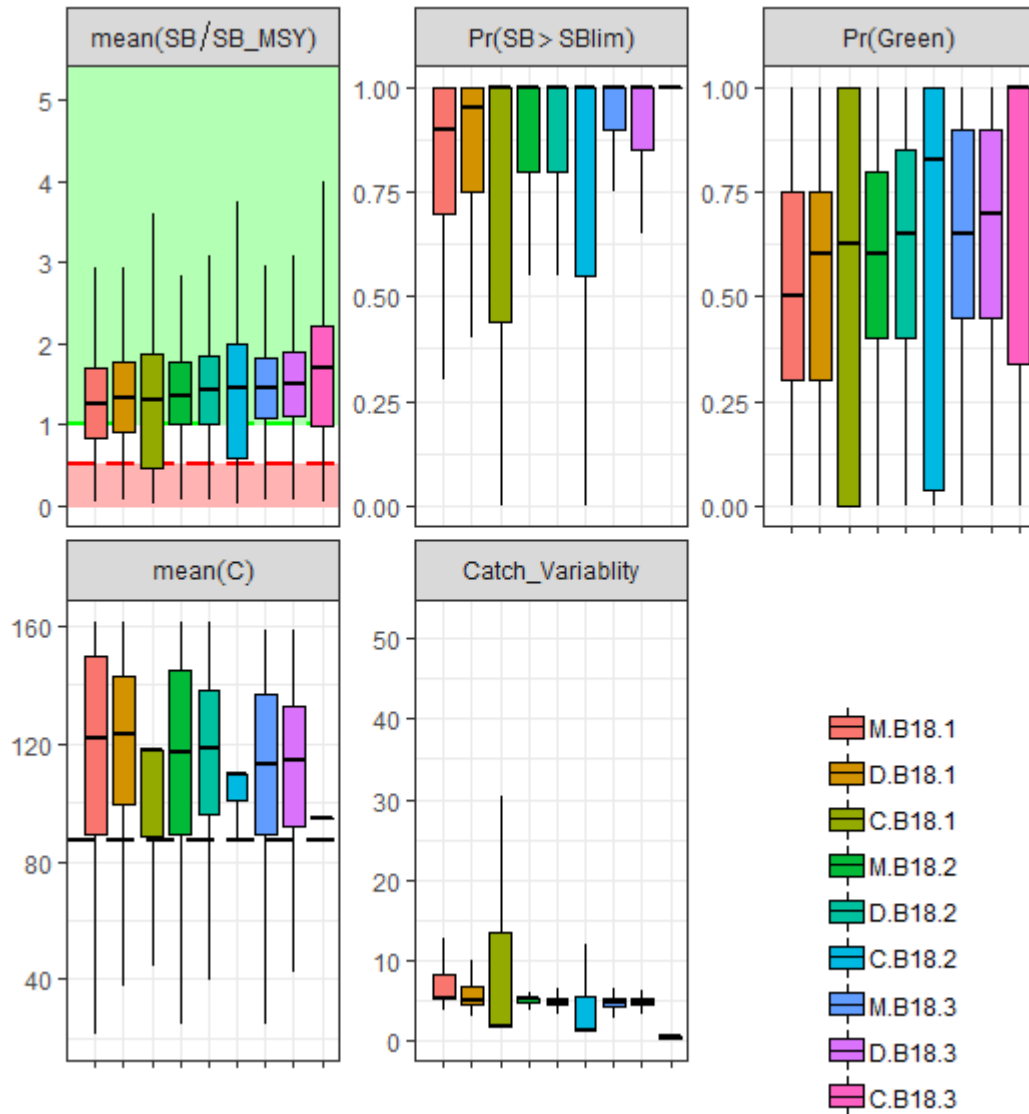
Figure 43. Bigeye robustness case (OMrobB18.5.qTrend3 - increasing longline catchability 3% per annum) - Boxplots comparing candidate MPs with respect to key performance measures averaged over the period 2019 - 2038. Horizontal line is the median, boxes represent 25th - 75th percentiles, thin lines represent 10th - 90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB$_{MSY}$ performance measure. The horizontal dashed black line is 2016 catch.
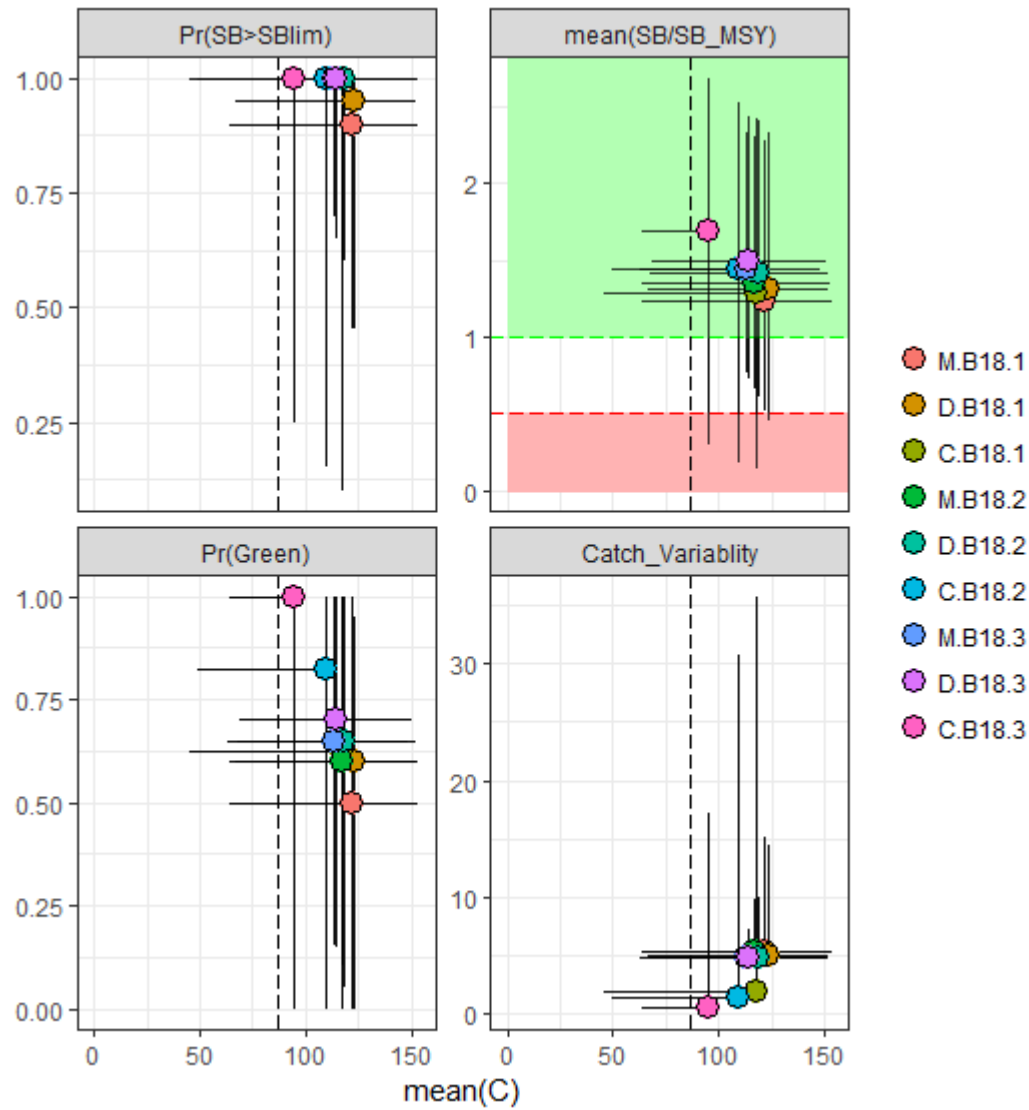
Figure 44. Bigeye robustness case (OMrobB18.5.qTrend3 - increasing longline catchability 3% per annum) - Trade-off plots comparing candidate MPs with respect to catch on the X-axis, and 4 other key performance measures on the Y-axis, each averaged over the period 2019 - 2038. Circle is the median, lines represent 10th-90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB$_{MSY}$ performance measure. The dashed vertical black line is 2016 catch.
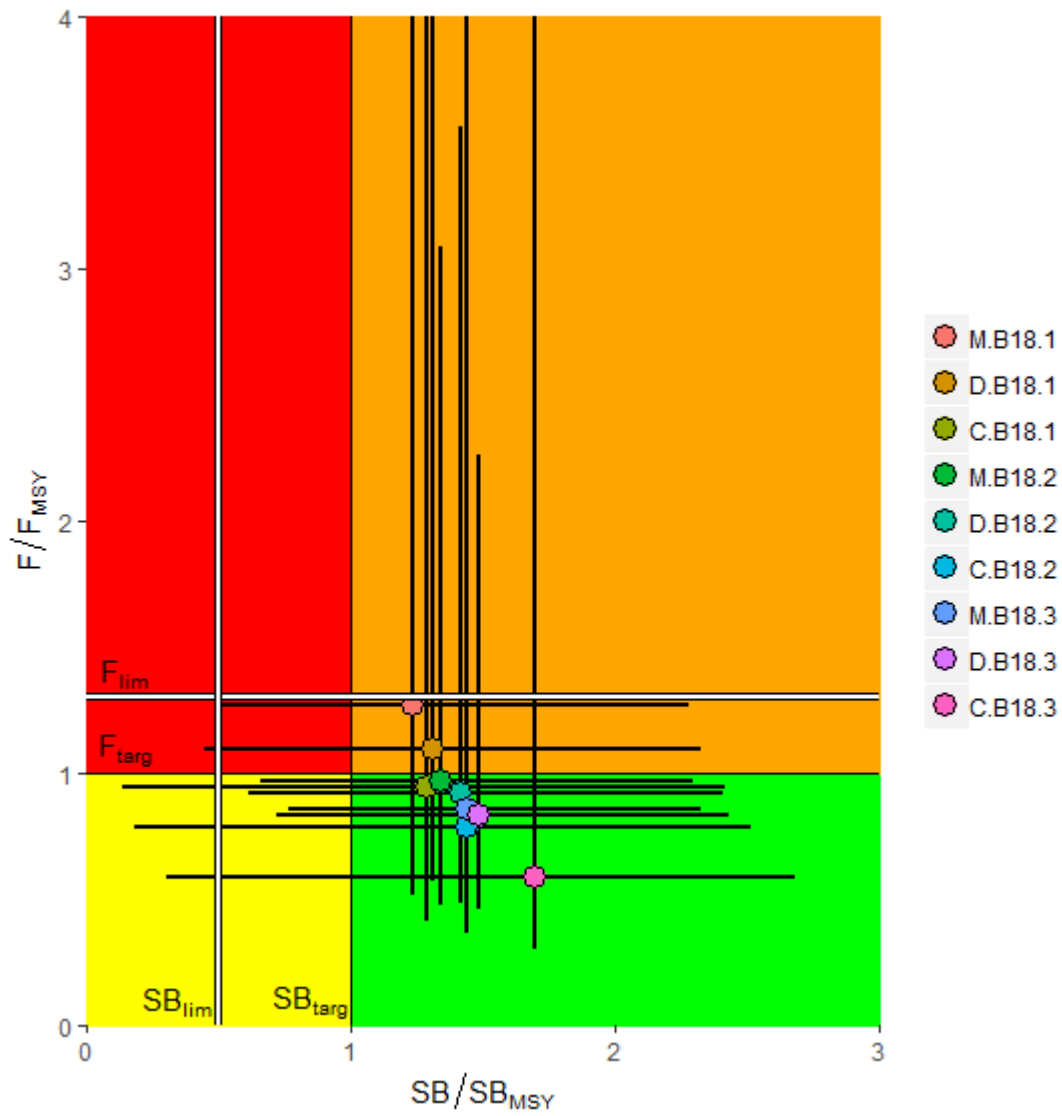
Figure 45. Bigeye robustness case (OMrobB18.5.qTrend3 - increasing longline catchability 3% per annum) - Kobe plot comparing candidate MPs on the basis of the expected 20 year average (2019-2038) performance. Circle is the median, lines represent 10th-90th percentiles.
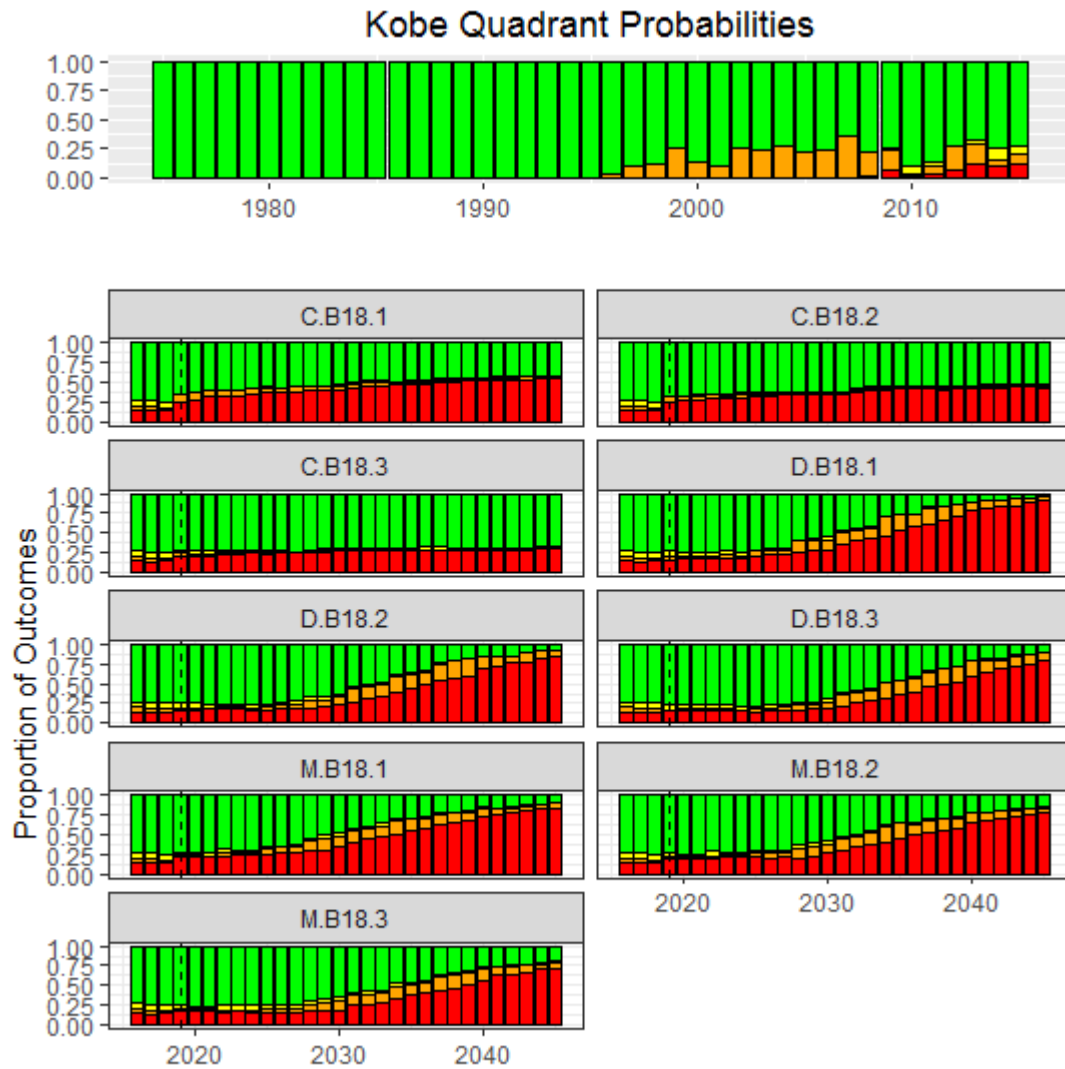
Figure 46. Bigeye robustness case (OMrobB18.5.qTrend3 - increasing longline catchability 3% per annum) - Proportion of simulations in each of the Kobe quadrants over time for each of the candidate MPs. Historical estimates are included in the top panel. The lower panels are projections, with the first MP application indicated by the broken vertical line (2019).

Figure 47. Bigeye robustness case (OMrobB18.5.qTrend3 - increasing longline catchability 3% per annum) - Time series of spawning stock size for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year
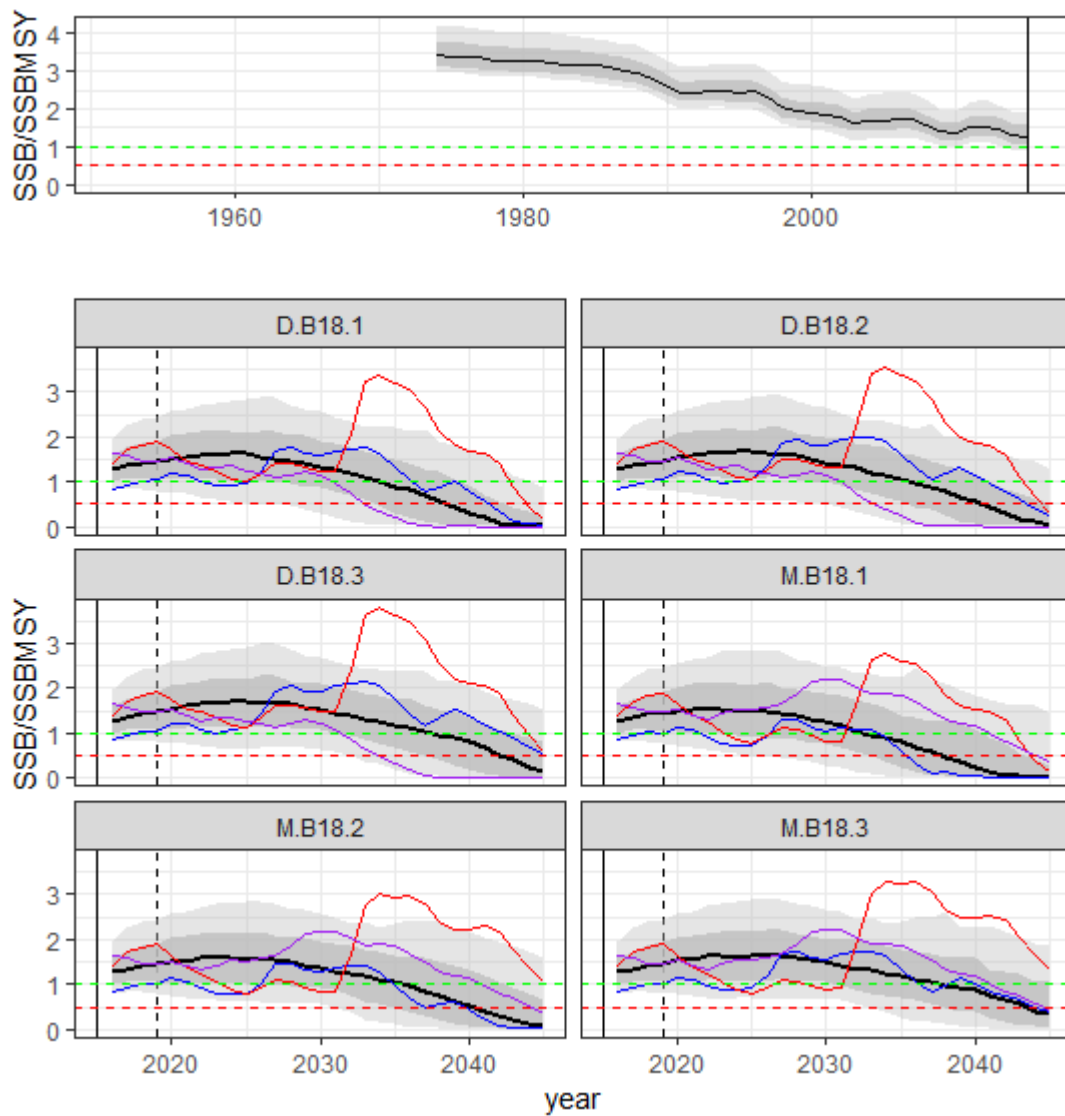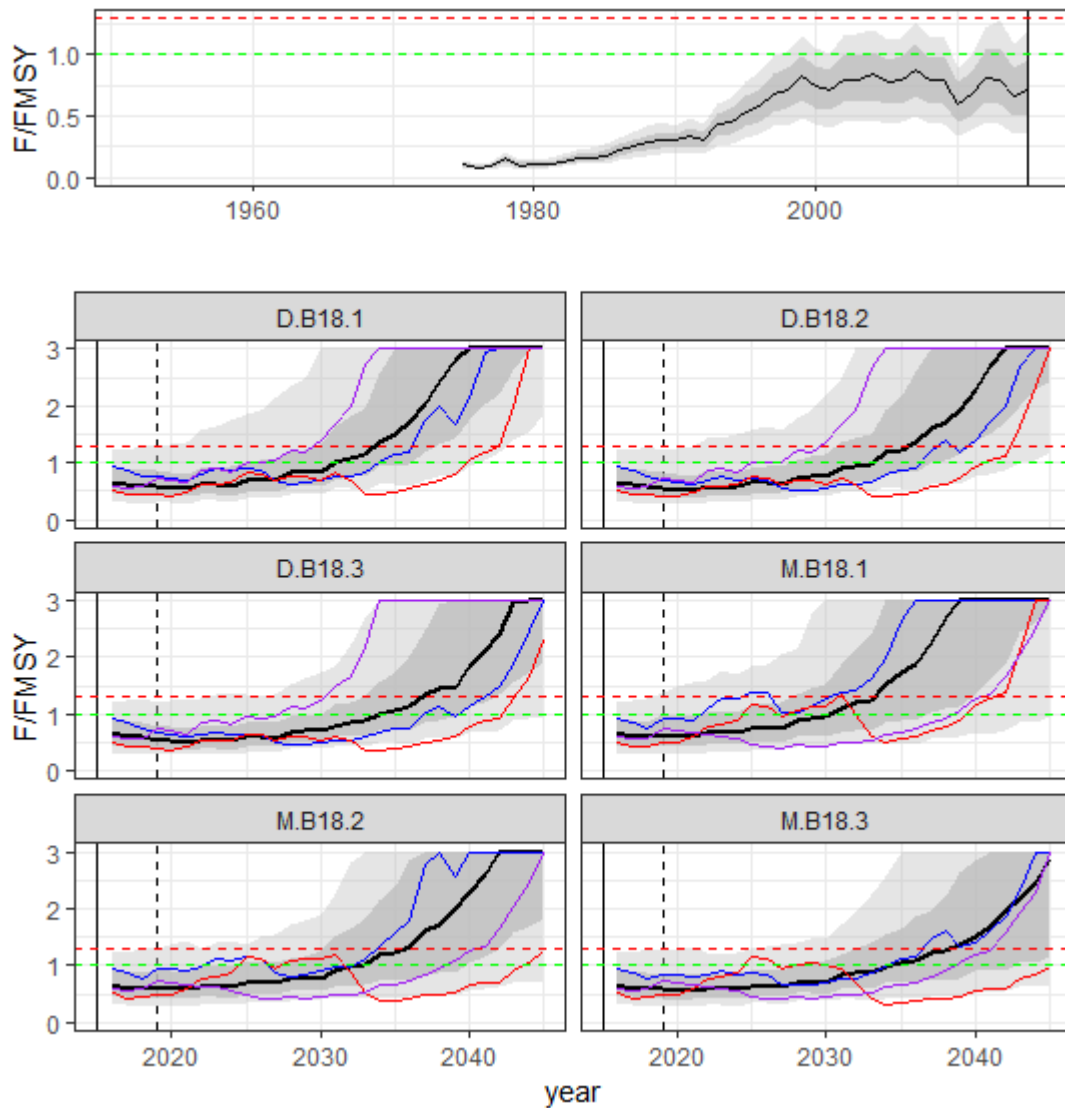
Figure 48. Bigeye robustness case (OMrobB18.5.qTrend3 - increasing longline catchability 3% per annum) - Time series of fishing intensity (Upper bound truncated at F = 3) for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.

Figure 49. Bigeye robustness case (OMrobB18.5.qTrend3 - increasing longline catchability 3% per annum) - Time series of catch for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. The broken black horizontal line represents recent (2016) catch. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
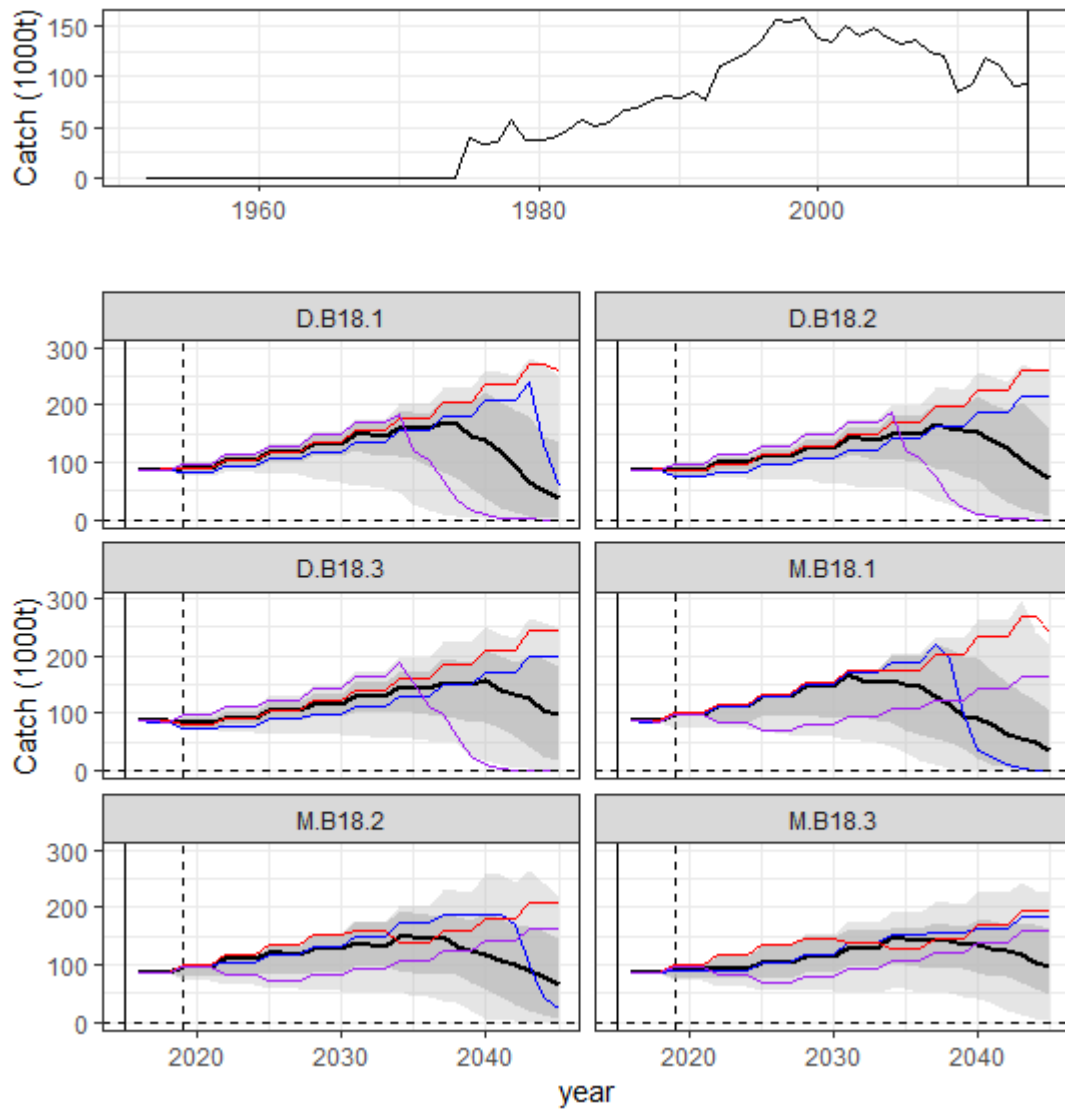
Yellowfin Tuna MP evaluation update for WPM 2018

Management Procedure Evaluation Status

- Management Procedure (MP) evaluation is being pursued in the strict sense (i.e. as in the International Whaling Commission and Commission for the Conservation of Southern Bluefin Tuna), in which the data to be input to the MP, the analysis, and the Harvest Control Rule (HCR) are all defined in advance and simulation-tested together.
- The yellowfin reference case Operating Model (simulator) is being iteratively developed in line with IOTC technical working party requests (WPTT and WPM). Currently, the highest priority concern is attaining a reference case OM that represents the main uncertainties of the yellowfin stock, and is plausibly consistent with the data and qualitative judgement of the technical working parties.
- A small set of generic MPs has been evaluated for each of the tuning objectives requested by the TCMP-02 (2018) and are presented here, to illustrate typical performance, and facilitate feedback for the next iteration.
- The main focus for the technical working parties should be the evaluation of the reference set and robustness set OMs, and providing ideas for alternative MPs (once the management objectives are better understood). The TCMP should focus on management objectives and MP tuning targets.
- The earliest target date for adoption of an MP was identified as 2019, however it was clear in the TCMP 2018 that further work to illustrate trade-offs and refine management objectives will be required at the TCMP 2019. Scientific and technical support funding has been identified to support the work to Dec 2019 through the GEF-ABNJ-FAO project and CSIRO, Australia.

Yellowfin MP Development Guidance from TCMP-02 (2018)

Tuning objectives refer to a key management objective that the MPs can achieve precisely (e.g. achieving SB ≥ SB_{MSY} with a 50% probability by 2024). The tuning objective normally relates to a desirable biomass (in terms of the risk of exceeding reference points and/or a rebuilding timeframe), and has a very strong influence on the obtainable yield (because biomass risk and attainable catch are closely related). Tuning ensures that candidate MPs are identical with respect to this high priority objective, making it easier to select among MPs on the basis of performance with respect to secondary management objectives (e.g. yield and catch stability). Ideally the Commission will have narrowed down the tuning objectives to 1 or 2 before MP selection. This will allow MP developers to focus on MP development. TCMP-02 (2018) defined 3 interim yellowfin tuning objectives, which differ only by the rate of rebuilding to target levels:

TY18.1: Pr(SB(2024)>=SB(MSY)) = 0.5. Average SB in 2024 exceeds SB_{MSY} in exactly 50% of the simulations). This was retained from the results of TCMP02 (in which it was labelled TY5)

TY18.2: Pr(SB(2029)>=SB(MSY)) = 0.5. Average SB in 2029 exceeds SB_{MSY} in exactly 50% of the simulations).

TY18.3: Pr(SB(2034)>=SB(MSY)) = 0.5. Average SB in 2034 exceeds SB_{MSY} in exactly 50% of the simulations).

TCMP-02 (2018) implicitly endorsed Total Allowable Catch (TAC) setting every 3 years (held constant between settings), and recommended further exploration of alternative TAC change constraints around the 15% level (the difference between the new TAC and the previous TAC)

Summary of Yellowfin Candidate MP Performance against the reference case OM (OMrefY18.1)

MP results from the reference set OM (OMrefY18.1) are summarized in the standard format in Figure 50 - Figure 56, and Table 3 - Table 4, from which we note:

- There appears to be relatively little difference in MP behaviour among the three new tuning objectives. This arises because the stock biomass rebuilding objective is reasonably easy to attain in the shortest timeframe. The degree of variability in performance among tuning objectives for the feedback-based MPs (e.g. Figure 50 - Figure 51) does not appear to be substantially different from the variability among MPs for the central tuning level (Figure 57 - Figure 58).
- All of the MPs and tuning levels examined suggest that sizable average catch reductions (to around 300Kt) will be required over the 20 year summary period, with a >90% chance that the average catch will need to drop below recent levels (413Kt).
- All of the MPs and tuning levels examined indicate a median performance (over the 20 year summary period) can be maintained in the green Kobe zone, and close to 90% of realizations result in a mean that is above the biomass limit.

Summary of Yellowfin Candidate MP Performance against the robustness tests

OMrobY18.1.recShock - as would be expected, a recruitment failure of the magnitude estimated for yellowfin in the 2000s increases the biomass risk over the 20 year summary period (Figure 60 - Figure 66). The median of the (feedback-based) MPs (which were all in the green zone for the reference case), were all in the yellow Kobe zone, with an elevated risk of breaching the SB limit reference point. However, for all of the feedback-based MPs, the median biomass decline was halted in the early-2020s and biomass subsequently continuously increased to the end of the projection period.

OMrobY18.1.qTrend3 - if there is an unrecognized 3% per annum increase in longline catchability going forward (i.e. independent of conditioning assumptions), the MPs appear to cope reasonably well in the 20 year performance summary period (Figure 67 - Figure 73). Similar to the reference case, all of the MPs and tuning levels maintain the stock in or near the Kobe green zone, with almost 90% probability of maintaining SB above the limit (on average). The model-based MPs show a stronger SB decline in the latter 10 years of the projections than the data-based MPs. Since both are closely informed by CPUE, it is not obvious why this should be the case. This is an example where the robustness test may provide useful model selection insight (though we would want to examine alternative model-based MPs before concluding that this is a general conclusion).

Feedback Requests for the TCMP

- Assuming that any changes proposed for the reference case OMs do not substantially change the central tendencies of the performance (noting that the potentially controversial approach for defining the yellowfin OM is not yet agreed):
  - Should we add additional tuning levels to the TCMP requests, either to i) expand the range of results shown, or ii) suggest that tuning might be pursued in an alternative currency that is easier to interpret and compare among species and from the standard output graphics (e.g. SB/SBMSY)?

- Are the robustness scenarios tested worth showing to the TCMP and should others be considered? Should the robustness tests be presented differently from the reference case?
- Further examination of MPs:
    - numerical stability of the production model needs to be systematically evaluated. To date, MP performance has been evaluated for a particular implementation, such that: i) there may be scope to improve MP performance if another implementation can make better inferences, and ii) the current MP performance may be predicated on a population model that fails in a particular consistent fashion (re-tuning would be required if a more reliable model was adopted). We have not noted obvious performance problems to date, but deterministic production models often have poor capacity to fit populations with complicated recruitment dynamics
    - the implications of the divergence between the quota and catch (due to explicit implementation error, or numerical limits to the quota extraction in high F scenarios) on the MP should be examined.
    - If we can obtain more feedback on desirable MP performance characteristics, it may be possible to further customize MP behaviour, e.g. with non-linear relationships or time series structure to help the transition period between current and target stock status.
- It may be worth presenting additional tuning objectives for yellowfin that broaden the performance range among tuning levels. Alternatively, it may be worth demonstrating tuning objectives that narrow the performance among MPs. i.e. A single, easily achievable tuning objective can be achieved in many ways (there are many ways to draw a line through a point). A more restrictive objective provides a clearer development goal to aim for.
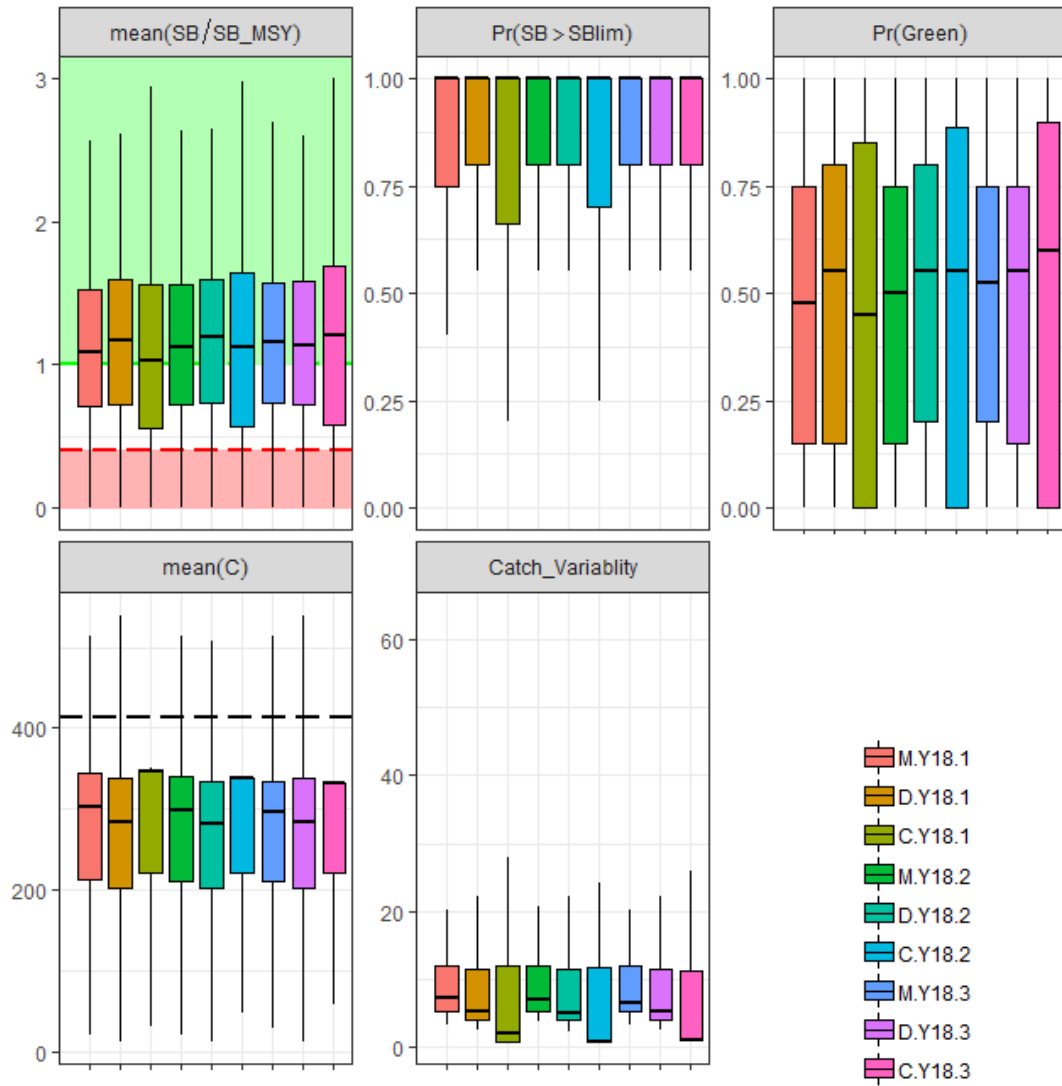
Figure 50. YFT reference case (OMrefY18.1) - Boxplots comparing candidate MPs with respect to key performance measures averaged over the period 2019 - 2038. Horizontal line is the median, boxes represent 25th - 75th percentiles, thin lines represent 10th - 90th percentiles. Red and green horizontal lines represent the interim limit and target reference points. The horizontal dashed black line is 2016 catch.
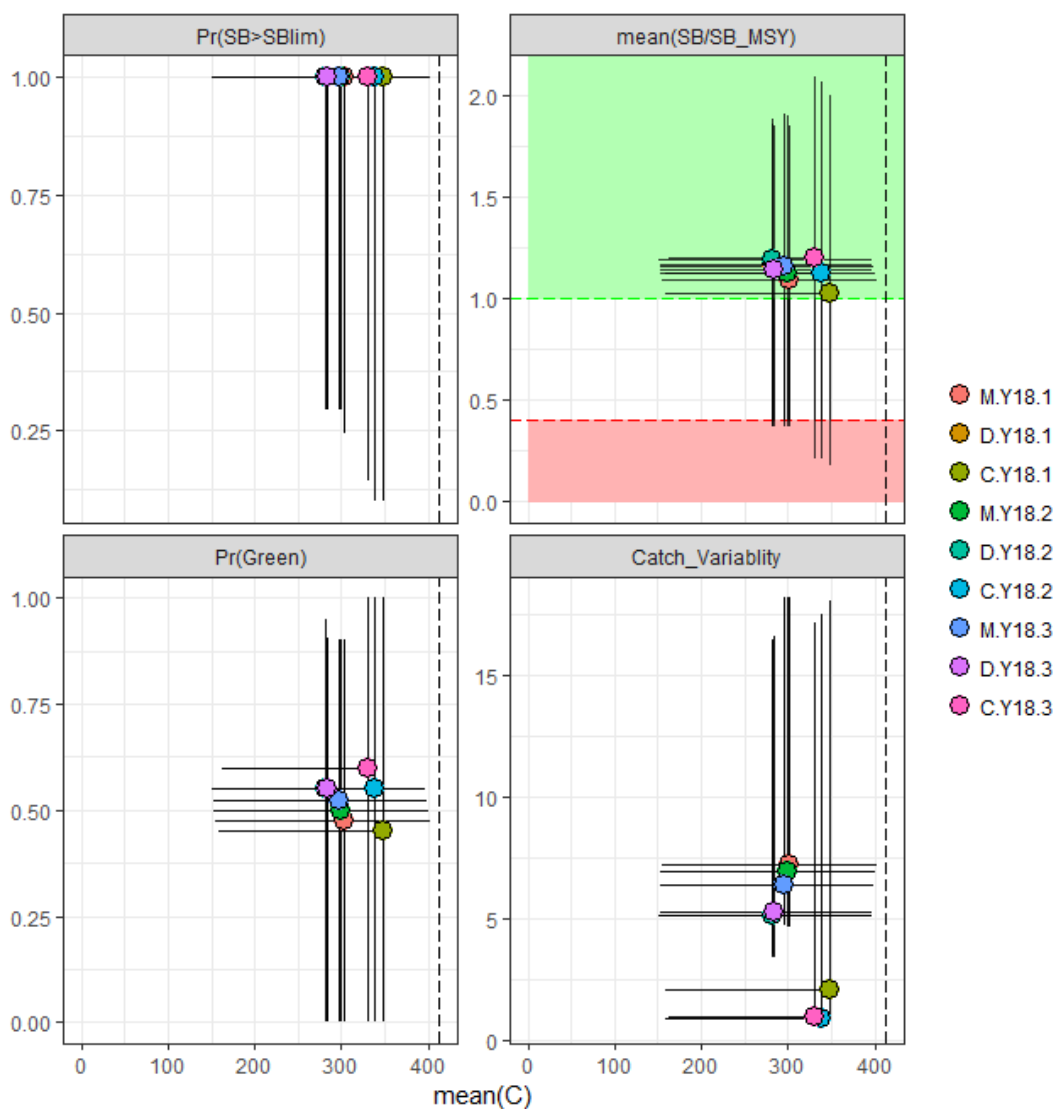
Figure 51. YFT reference case (OMrefY18.1) - Trade-off plots comparing candidate MPs with respect to catch on the X-axis, and 4 other key performance measures on the Y-axis, each averaged over the period 2019 - 2038. Circle is the median, lines represent 10th-90th percentiles. Red and green horizontal lines represent the interim limit and target reference points. The dashed vertical black line is 2016 catch.

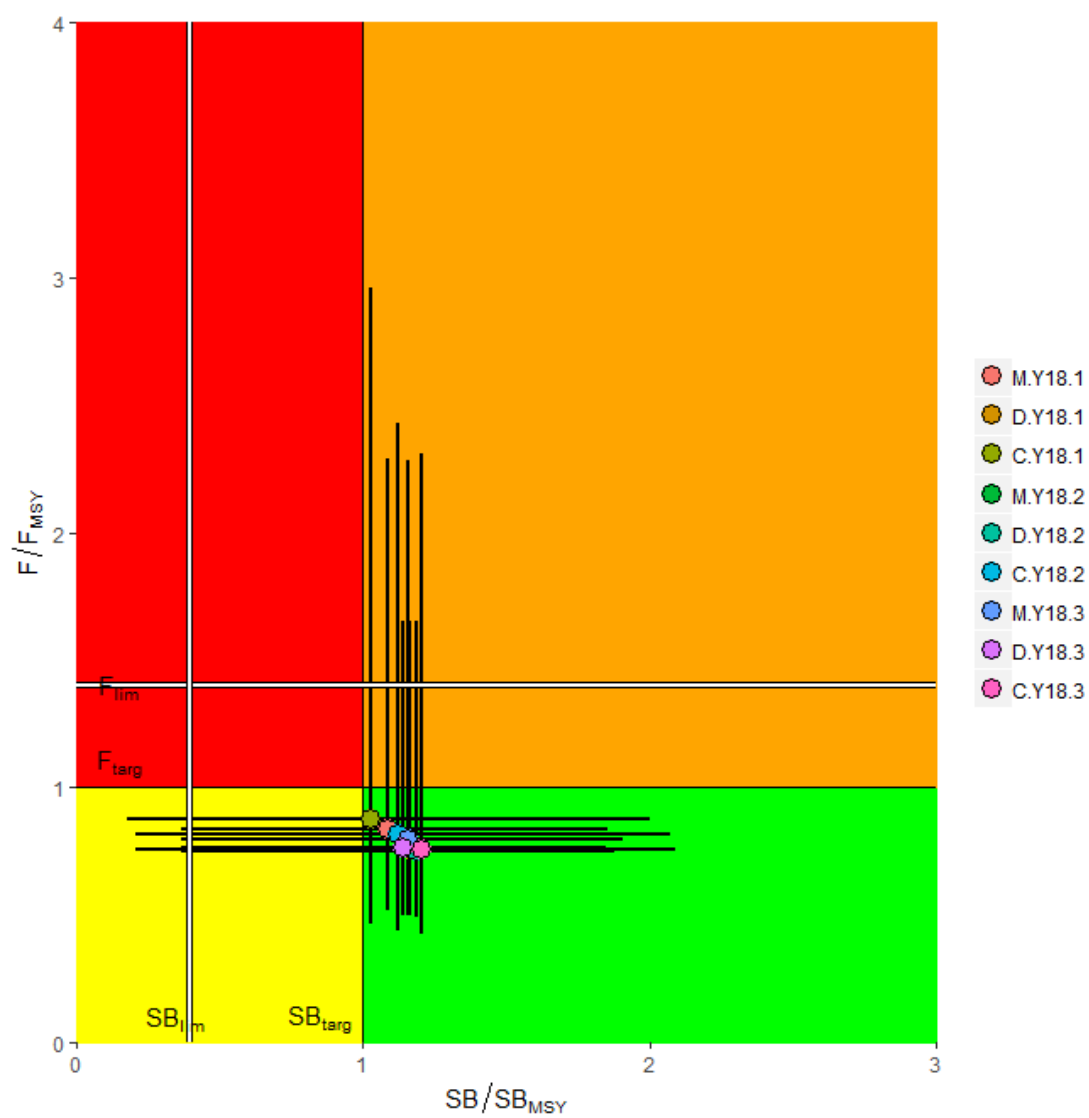*Figure 52. YFT reference case (OMrefY18.1) - Kobe plot comparing candidate MPs on the basis of the expected 20 year average (2019-2038) performance. Circle is the median, lines represent 10th-90th percentiles.*
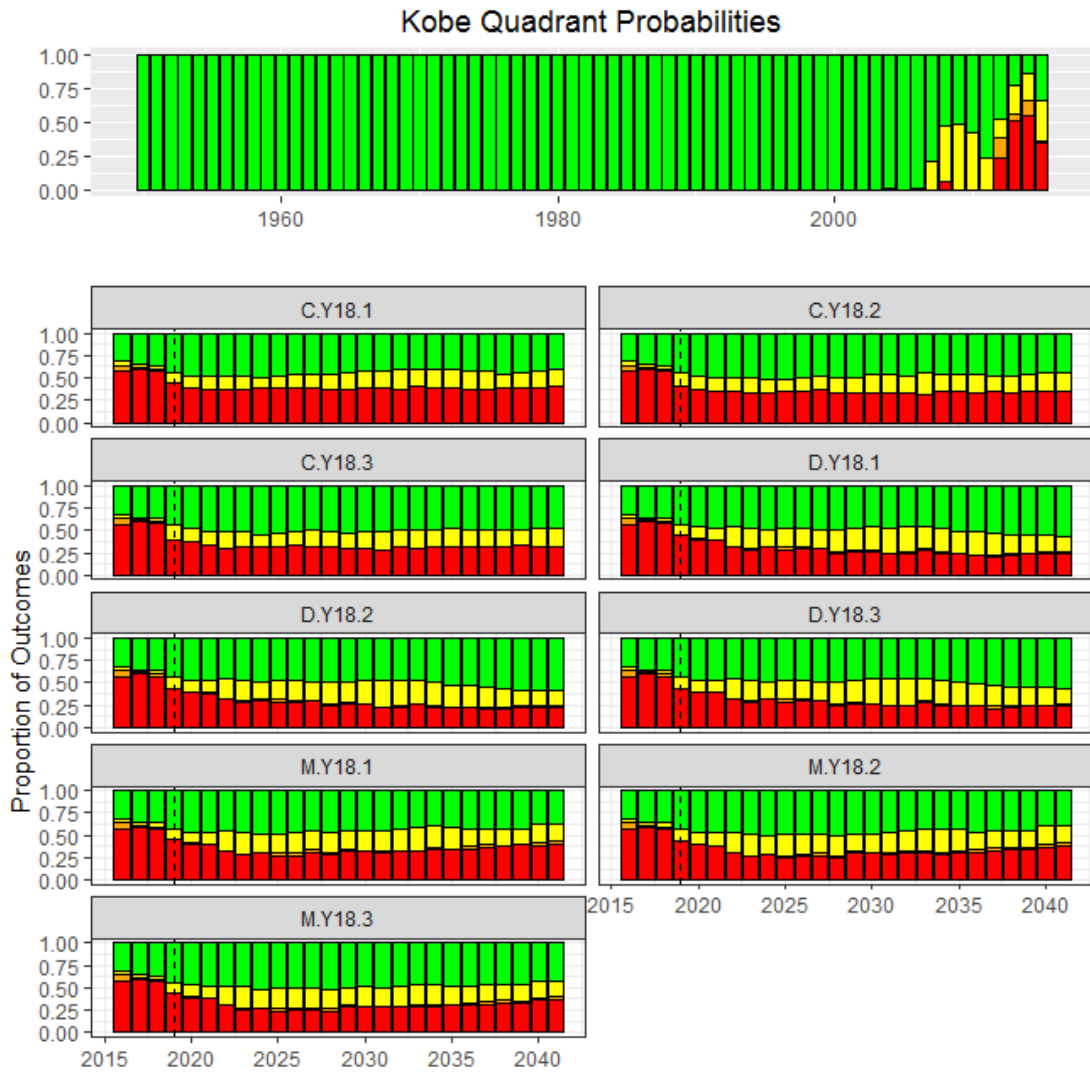
Figure 53. YFT reference case (OMrefY18.1) - Proportion of simulations in each of the Kobe quadrants over time for each of the candidate MPs. Historical estimates are included in the top panel.
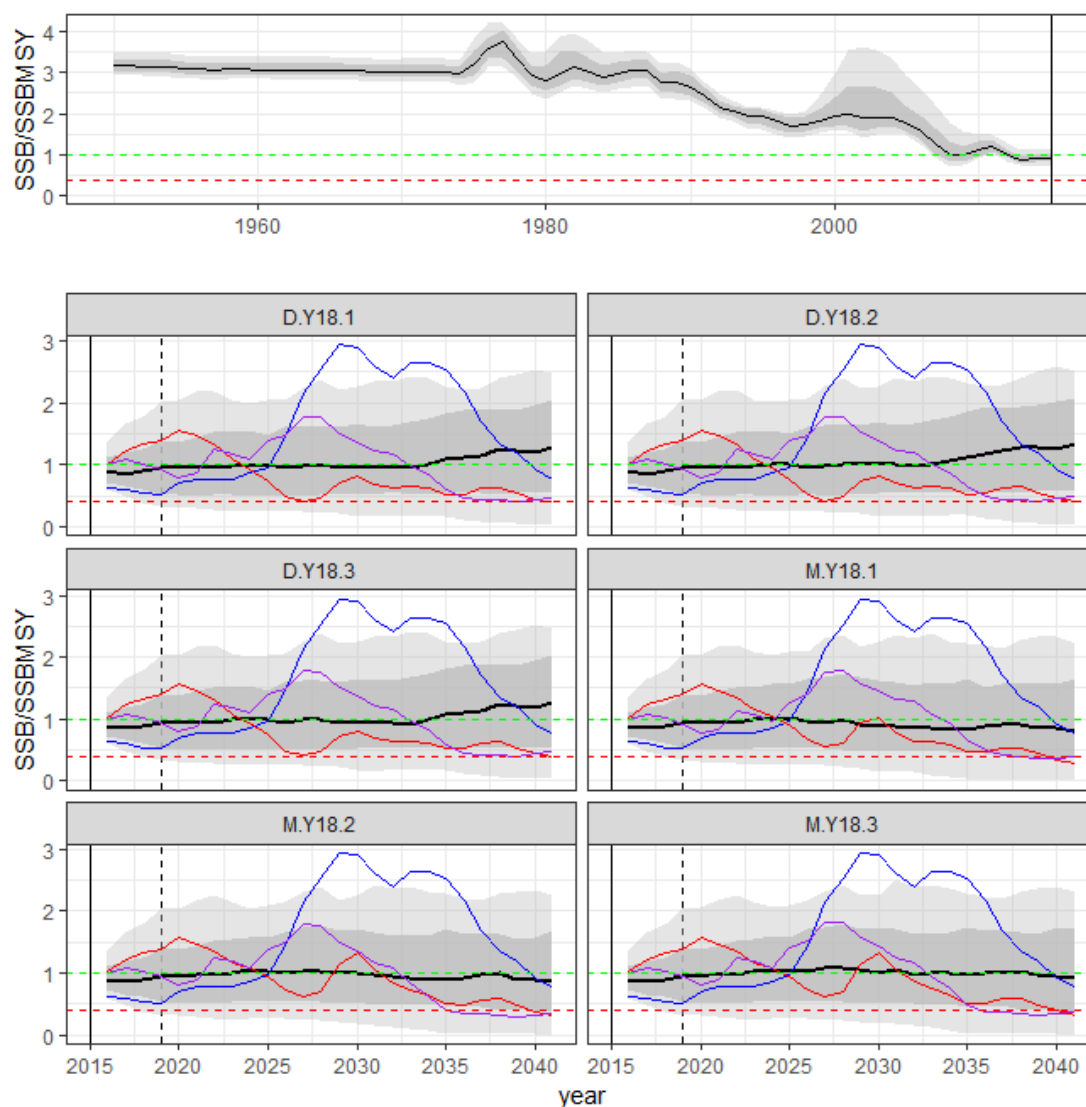
Figure 54. YFT reference case (OMrefY18.1) - Time series of spawning stock size for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.

Figure 55. YFT reference case (OMrefY18.1) - Time series of fishing intensity (Upper bound truncated at F = 3) for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
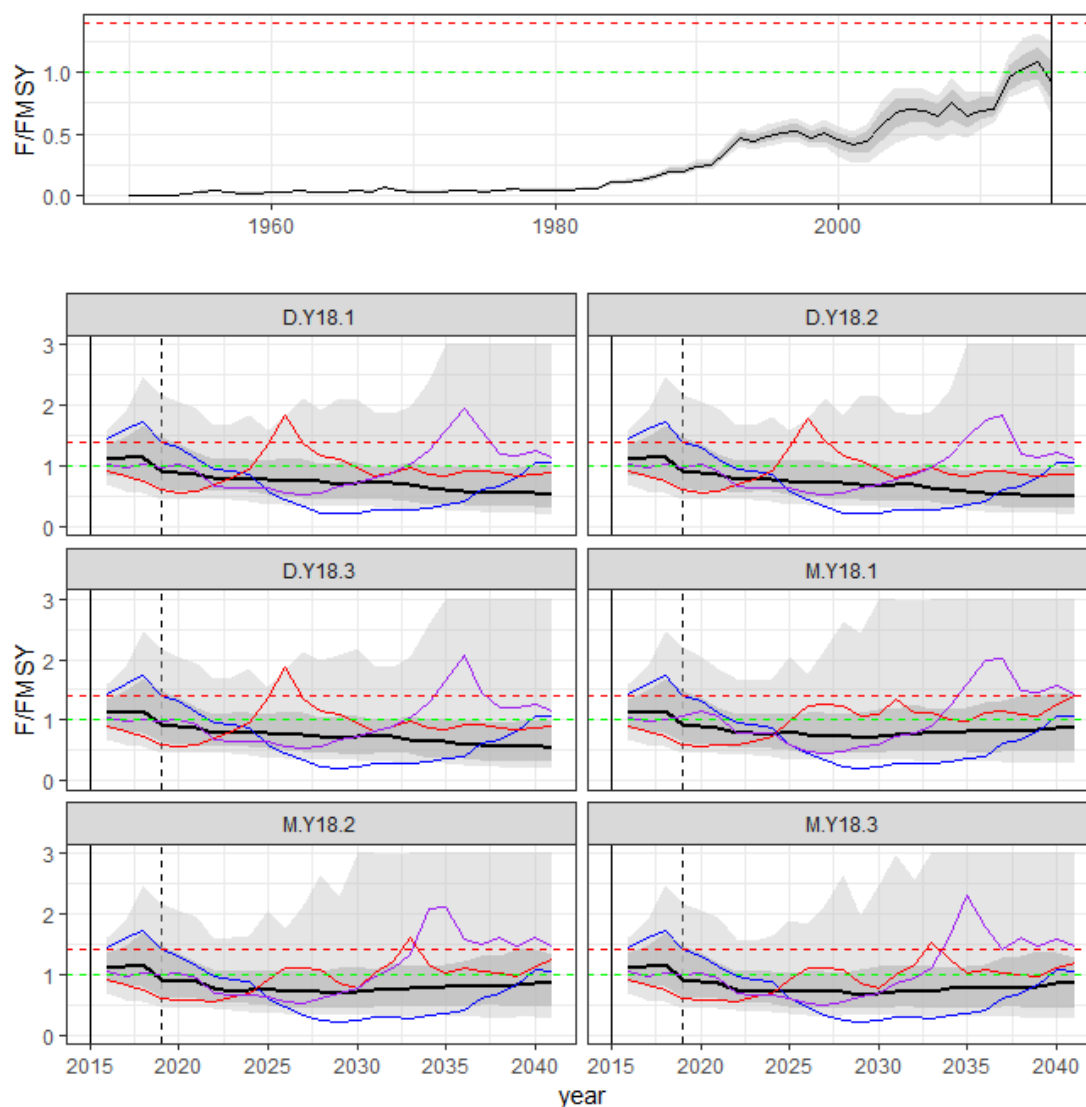
Figure 56. YFT reference case (OMrefY18.1) - Time series of catch for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. The broken black horizontal line represents recent (2016) catch. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
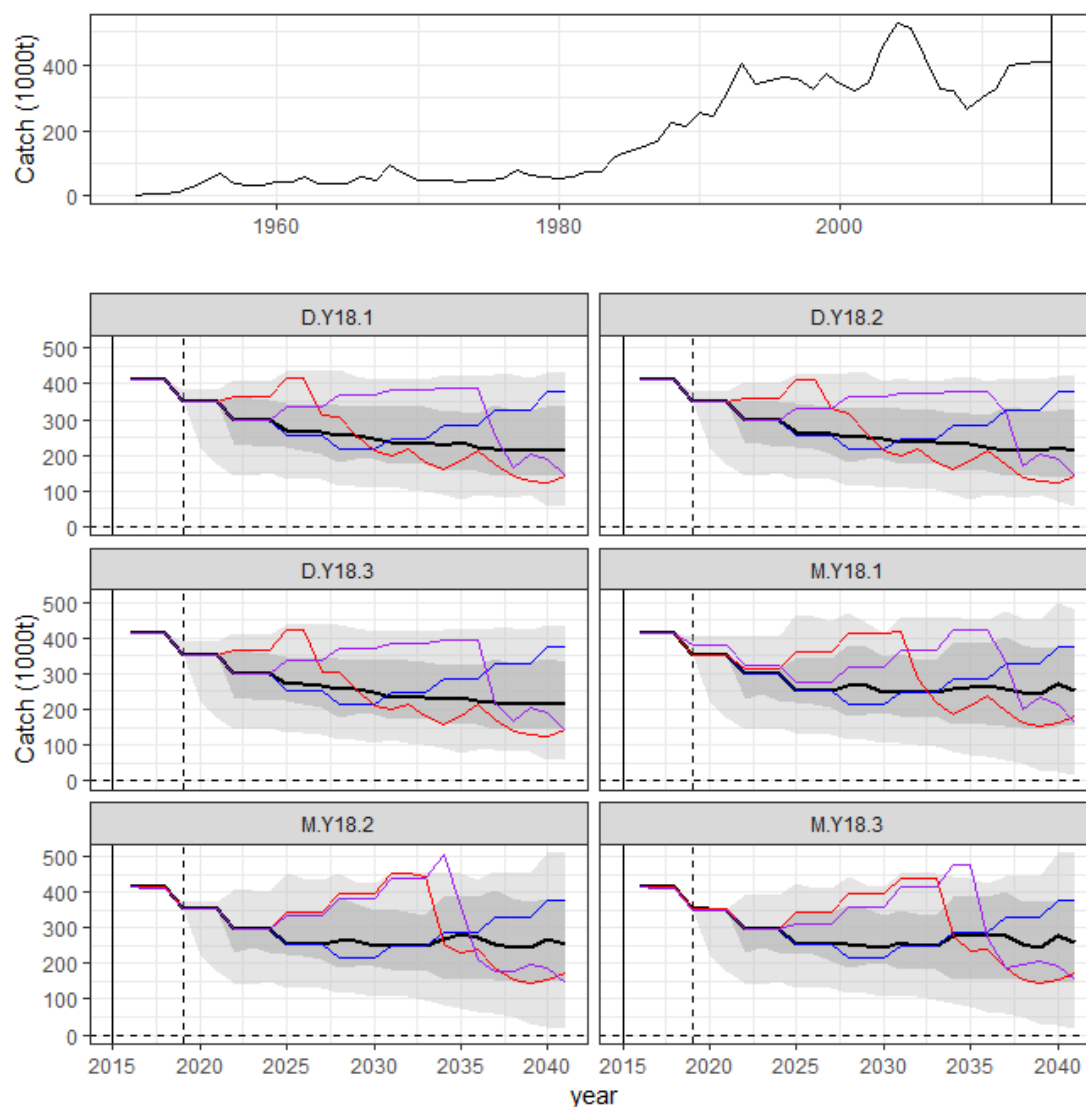
Table 3. YFT reference case (OMrefY18.1) - Performance of candidate MPs with respect to key performance measures (averaged over the period 2019-2038). Shading indicates the relative performance (darker = better). Note that 2016 catch was 413 000 t, and the mean catch from 1992-2016 was 374 000 t.

Management Procedure	Performance Measure				
	SB/SB_{MSY}	Prob(Green)	Prob(SB>limit)	Mean Catch	Catch Variability
M.Y18.1	1.03 (0.55-1.56)	0.45	0.79	347.3 (220.8-349.5)	2.10
D.Y18.1	1.12 (0.57-1.64)	0.49	0.80	338.5 (220.4-338.7)	0.91
C.Y18.1	1.21 (0.58-1.69)	0.51	0.82	331.0 (221.7-331.2)	1.00
M.Y18.2	1.16 (0.72-1.59)	0.49	0.83	282.7 (202.1-337.8)	5.17
D.Y18.2	1.19 (0.73-1.60)	0.50	0.83	281.0 (201.3-333.1)	5.14
C.Y18.2	1.14 (0.72-1.59)	0.48	0.83	284.3 (202.5-338.6)	5.31
M.Y18.3	1.09 (0.71-1.52)	0.46	0.81	302.0 (213.1-344.2)	7.25
D.Y18.3	1.12 (0.72-1.56)	0.48	0.81	298.4 (210.8-340.6)	6.95
C.Y18.3	1.16 (0.73-1.58)	0.49	0.82	296.2 (210.8-334.2)	6.43

Table 4a. YFT reference case (OMrefY18.1) - Candidate MP performance for standard IOTC performance measures for the year 2019.

Status : maximise stock status		1 year average								
		M.Y18.1	D.Y18.1	C.Y18.1	M.Y18.2	D.Y18.2	C.Y18.2	M.Y18.3	D.Y18.3	C.Y18.3
Mean spawner biomass relative to pristine	SB/SB_0	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Minimum spawner biomass relative to pristine	SB/SB_0	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Mean spawner biomass relative to SBMSY	SB/SB_{MSY}	0.94	0.94	0.95	0.94	0.94	0.94	0.94	0.94	0.94
Mean fishing mortality relative to FMSY	F/F_{tar}	0.91	0.88	0.86	0.92	0.92	0.92	0.94	0.92	0.92
Mean fishing mortality relative to target	F/F_{MSY}	0.91	0.88	0.86	0.92	0.92	0.92	0.94	0.92	0.92
Probability of being in Kobe green quadrant	SB,F	0.46	0.46	0.46	0.46	0.46	0.46	0.45	0.46	0.46
Probability of being in Kobe red quadrant	SB,F	0.43	0.40	0.39	0.44	0.43	0.44	0.44	0.43	0.43
Safety : maximise the probability of remaining above low stock status (i.e. minimise risk)										
Probability of spawner biomass being above 20% of SB0	SB	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Probability of spawner biomass being above BLim	SB	0.85	0.85	0.86	0.84	0.84	0.84	0.84	0.84	0.84
Yield : maximise catches across regions and gears										
Mean catch (1000 t)	C	349.49	338.66	331.13	351.28	351.25	351.28	351.23	351.18	351.07
Mean relative CPUE (aggregate)	C	0.86	0.83	0.82	0.88	0.88	0.88	0.88	0.88	0.88
Mean catch relative to MSY	C/MSY	0.67	0.67	0.68	0.66	0.66	0.66	0.66	0.67	0.67
Stability: maximise stability in catches to reduce commercial uncertainty										
Mean absolute proportional change in catch	C	15.40	18.02	19.84	15.00	15.00	15.00	15.00	15.00	15.00
% Catch coefficient of variation	C	NA	NA	NA	NA	NA	NA	NA	NA	NA
Probability of shutdown	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 4b. YFT reference case (OMrefY18.1) - Candidate MP performance for standard IOTC performance measures averaged over the years 2019-2024.

Status : maximise stock status		5 year average								
		M.Y18.1	D.Y18.1	C.Y18.1	M.Y18.2	D.Y18.2	C.Y18.2	M.Y18.3	D.Y18.3	C.Y18.3
Mean spawner biomass relative to pristine	SB/SB_0	0.32	0.32	0.33	0.31	0.32	0.31	0.31	0.32	0.32
Minimum spawner biomass relative to pristine	SB/SB_0	0.25	0.25	0.25	0.24	0.25	0.24	0.25	0.25	0.25
Mean spawner biomass relative to SBMSY	SB/SB_{MSY}	0.99	1.02	1.04	0.99	0.99	0.99	0.99	1.00	1.01
Mean fishing mortality relative to FMSY	F/F_{tar}	0.85	0.80	0.78	0.83	0.83	0.84	0.82	0.81	0.81
Mean fishing mortality relative to target	F/F_{MSY}	0.85	0.80	0.78	0.83	0.83	0.84	0.82	0.81	0.81
Probability of being in Kobe green quadrant	SB,F	0.48	0.49	0.51	0.47	0.47	0.47	0.46	0.47	0.48
Probability of being in Kobe red quadrant	SB,F	0.39	0.36	0.34	0.37	0.36	0.37	0.37	0.36	0.35
Safety : maximise the probability of remaining above low stock status (i.e. minimise risk)										
Probability of spawner biomass being above 20% of SB0	SB	0.68	0.69	0.70	0.68	0.69	0.68	0.68	0.69	0.69
Probability of spawner biomass being above BLim	SB	0.82	0.82	0.83	0.82	0.82	0.82	0.82	0.82	0.82
Yield : maximise catches across regions and gears										
Mean catch (1000 t)	C	349.45	338.62	331.09	330.48	330.37	330.59	330.02	330.00	329.94
Mean relative CPUE (aggregate)	C	0.80	0.78	0.76	0.82	0.81	0.82	0.80	0.79	0.79
Mean catch relative to MSY	C/MSY	0.77	0.79	0.80	0.77	0.77	0.77	0.78	0.78	0.78
Stability: maximise stability in catches to reduce commercial uncertainty										
Mean absolute proportional change in catch	C	3.09	3.61	3.98	6.00	6.00	6.00	6.00	6.00	6.00
% Catch coefficient of variation	C	0.00	0.00	0.00	0.09	0.09	0.09	0.09	0.09	0.09
Probability of shutdown	C	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02

Table 4c. YFT reference case (OMrefY18.1) - Candidate MP performance for standard IOTC performance measures averaged over the years 2019-2028.

Status : maximise stock status		10 year average								
		M.Y18.1	D.Y18.1	C.Y18.1	M.Y18.2	D.Y18.2	C.Y18.2	M.Y18.3	D.Y18.3	C.Y18.3
Mean spawner biomass relative to pristine	SB/SB_0	0.32	0.34	0.35	0.35	0.35	0.35	0.34	0.35	0.36
Minimum spawner biomass relative to pristine	SB/SB_0	0.19	0.21	0.22	0.20	0.21	0.20	0.19	0.21	0.21
Mean spawner biomass relative to SBMSY	SB/SB_{MSY}	1.01	1.06	1.10	1.10	1.10	1.09	1.07	1.10	1.12
Mean fishing mortality relative to FMSY	F/F_{tar}	0.87	0.80	0.77	0.82	0.80	0.84	0.83	0.78	0.77
Mean fishing mortality relative to target	F/F_{MSY}	0.87	0.80	0.77	0.82	0.80	0.84	0.83	0.78	0.77
Probability of being in Kobe green quadrant	SB,F	0.47	0.50	0.52	0.48	0.48	0.47	0.47	0.49	0.50
Probability of being in Kobe red quadrant	SB,F	0.39	0.35	0.33	0.33	0.32	0.33	0.33	0.31	0.30
Safety : maximise the probability of remaining above low stock status (i.e. minimise risk)										
Probability of spawner biomass being above 20% of SB0	SB	0.66	0.68	0.69	0.68	0.68	0.67	0.68	0.69	0.69
Probability of spawner biomass being above BLim	SB	0.81	0.82	0.83	0.82	0.82	0.82	0.82	0.83	0.83
Yield : maximise catches across regions and gears										
Mean catch (1000 t)	C	349.40	338.59	331.07	304.91	301.73	306.31	300.20	299.99	299.65
Mean relative CPUE (aggregate)	C	0.77	0.76	0.75	0.75	0.74	0.76	0.75	0.74	0.73
Mean catch relative to MSY	C/MSY	0.80	0.84	0.86	0.86	0.88	0.85	0.87	0.89	0.89
Stability: maximise stability in catches to reduce commercial uncertainty										
Mean absolute proportional change in catch	C	1.55	1.81	1.99	5.60	5.64	5.52	6.00	6.00	6.00
% Catch coefficient of variation	C	0.00	0.00	0.00	0.14	0.14	0.14	0.15	0.15	0.15
Probability of shutdown	C	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04

Table 4d. YFT reference case (OMrefY18.1) - Candidate MP performance for standard IOTC performance measures averaged over the years 2019-2038.

| Status : maximise stock status | | 20 year average | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | M.Y18.1 | D.Y18.1 | C.Y18.1 | M.Y18.2 | D.Y18.2 | C.Y18.2 | M.Y18.3 | D.Y18.3 | C.Y18.3 |
| Mean spawner biomass relative to pristine | SB/SB_0 | 0.32 | 0.35 | 0.38 | 0.37 | 0.38 | 0.37 | 0.35 | 0.35 | 0.37 |
| Minimum spawner biomass relative to pristine | SB/SB_0 | 0.15 | 0.16 | 0.18 | 0.15 | 0.15 | 0.15 | 0.13 | 0.13 | 0.14 |
| Mean spawner biomass relative to SBMSY | SB/SB_{MSY} | 1.03 | 1.12 | 1.21 | 1.16 | 1.19 | 1.14 | 1.09 | 1.12 | 1.16 |
| Mean fishing mortality relative to FMSY | F/F_{tar} | 0.88 | 0.82 | 0.76 | 0.76 | 0.75 | 0.76 | 0.83 | 0.82 | 0.80 |
| Mean fishing mortality relative to target | F/F_{MSY} | 0.88 | 0.82 | 0.76 | 0.76 | 0.75 | 0.76 | 0.83 | 0.82 | 0.80 |
| Probability of being in Kobe green quadrant | SB,F | 0.45 | 0.49 | 0.51 | 0.49 | 0.50 | 0.48 | 0.46 | 0.48 | 0.49 |
| Probability of being in Kobe red quadrant | SB,F | 0.38 | 0.34 | 0.32 | 0.29 | 0.28 | 0.29 | 0.33 | 0.31 | 0.30 |
| **Safety : maximise the probability of remaining above low stock status (i.e. minimise risk)** | | | | | | | | | | |
| Probability of spawner biomass being above 20% of SB0 | SB | 0.63 | 0.66 | 0.68 | 0.68 | 0.69 | 0.68 | 0.66 | 0.67 | 0.68 |
| Probability of spawner biomass being above BLim | SB | 0.79 | 0.80 | 0.82 | 0.83 | 0.83 | 0.83 | 0.81 | 0.81 | 0.82 |
| **Yield : maximise catches across regions and gears** | | | | | | | | | | |
| Mean catch (1000 t) | C | 347.34 | 338.51 | 331.01 | 282.66 | 281.03 | 284.32 | 301.98 | 298.45 | 296.23 |
| Mean relative CPUE (aggregate) | C | 0.75 | 0.73 | 0.71 | 0.68 | 0.67 | 0.68 | 0.71 | 0.71 | 0.71 |
| Mean catch relative to MSY | C/MSY | 0.83 | 0.93 | 0.99 | 0.95 | 0.97 | 0.94 | 0.90 | 0.93 | 0.95 |
| **Stability: maximise stability in catches to reduce commercial uncertainty** | | | | | | | | | | |
| Mean absolute proportional change in catch | C | 2.10 | 0.91 | 1.00 | 5.17 | 5.14 | 5.31 | 7.25 | 6.95 | 6.43 |
| % Catch coefficient of variation | C | 0.03 | 0.00 | 0.00 | 0.21 | 0.21 | 0.21 | 0.22 | 0.21 | 0.21 |
| Probability of shutdown | C | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
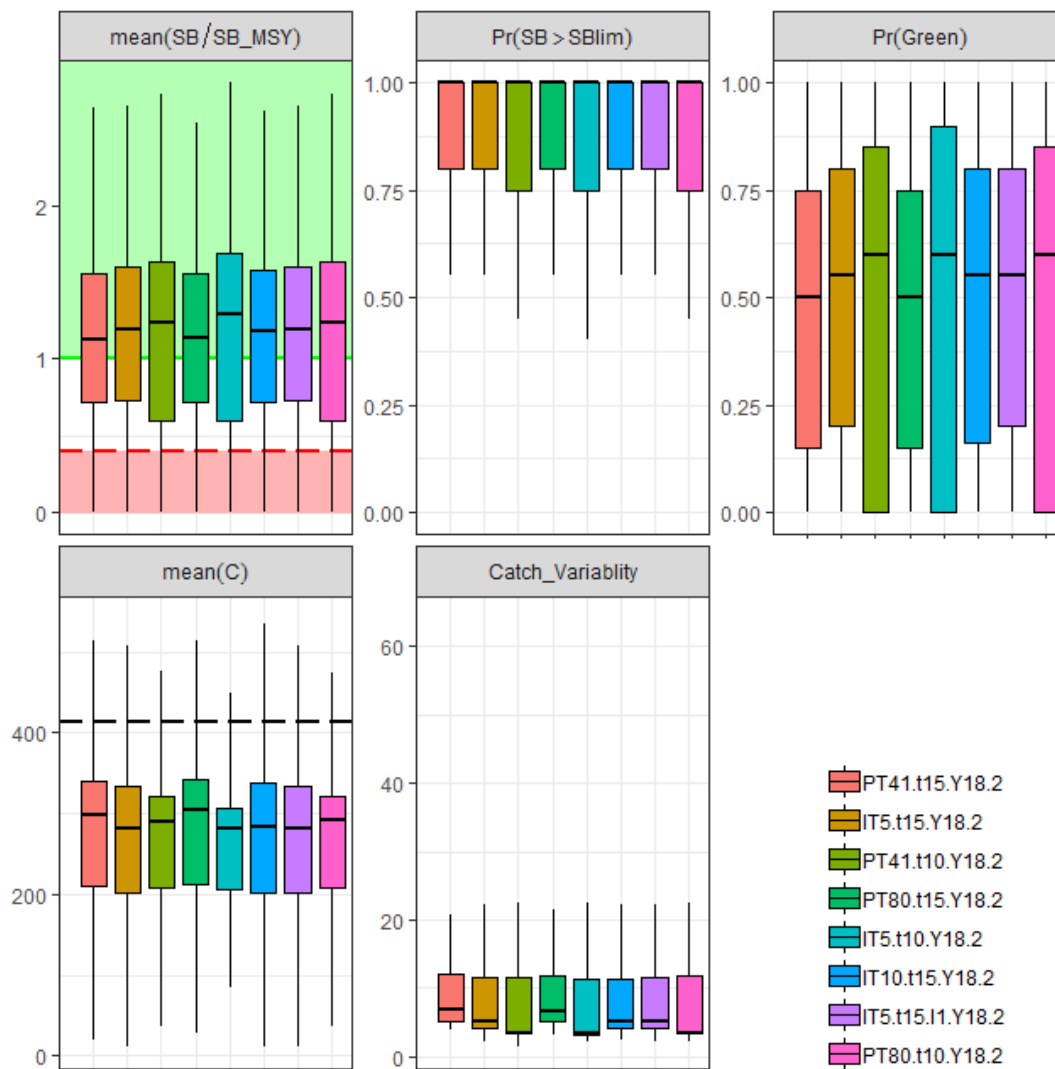
Figure 57. YFT reference case (OMrefY18.1) - Boxplots comparing a suite of model-based and data-based candidate MPs with respect to key performance measures averaged over the period 2019 - 2038, tuning objective Y18.2 only. Horizontal line is the median, boxes represent 25th - 75th percentiles, thin lines represent 10th - 90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB$_{MSY}$ performance measure. The horizontal dashed black line is 2016 catch.
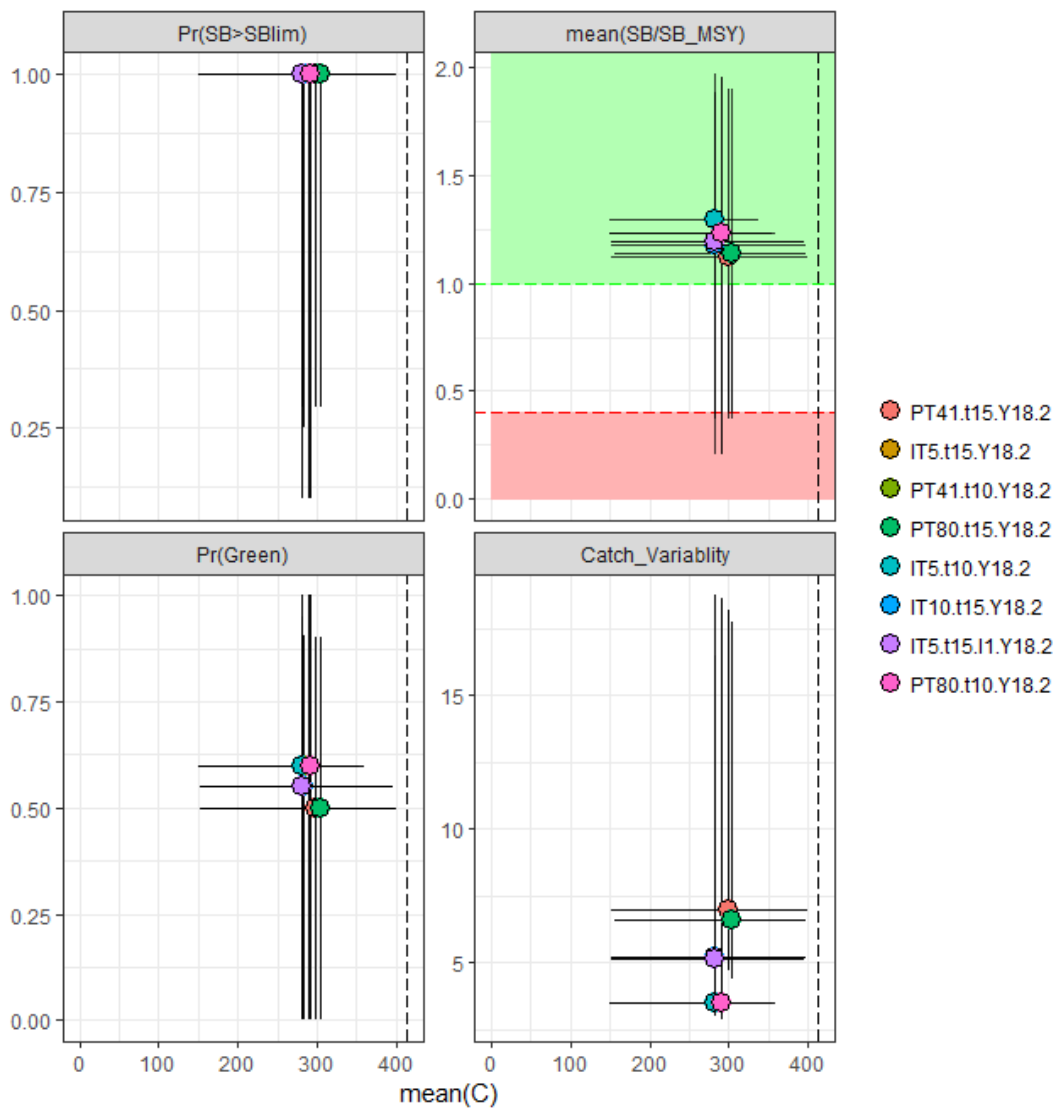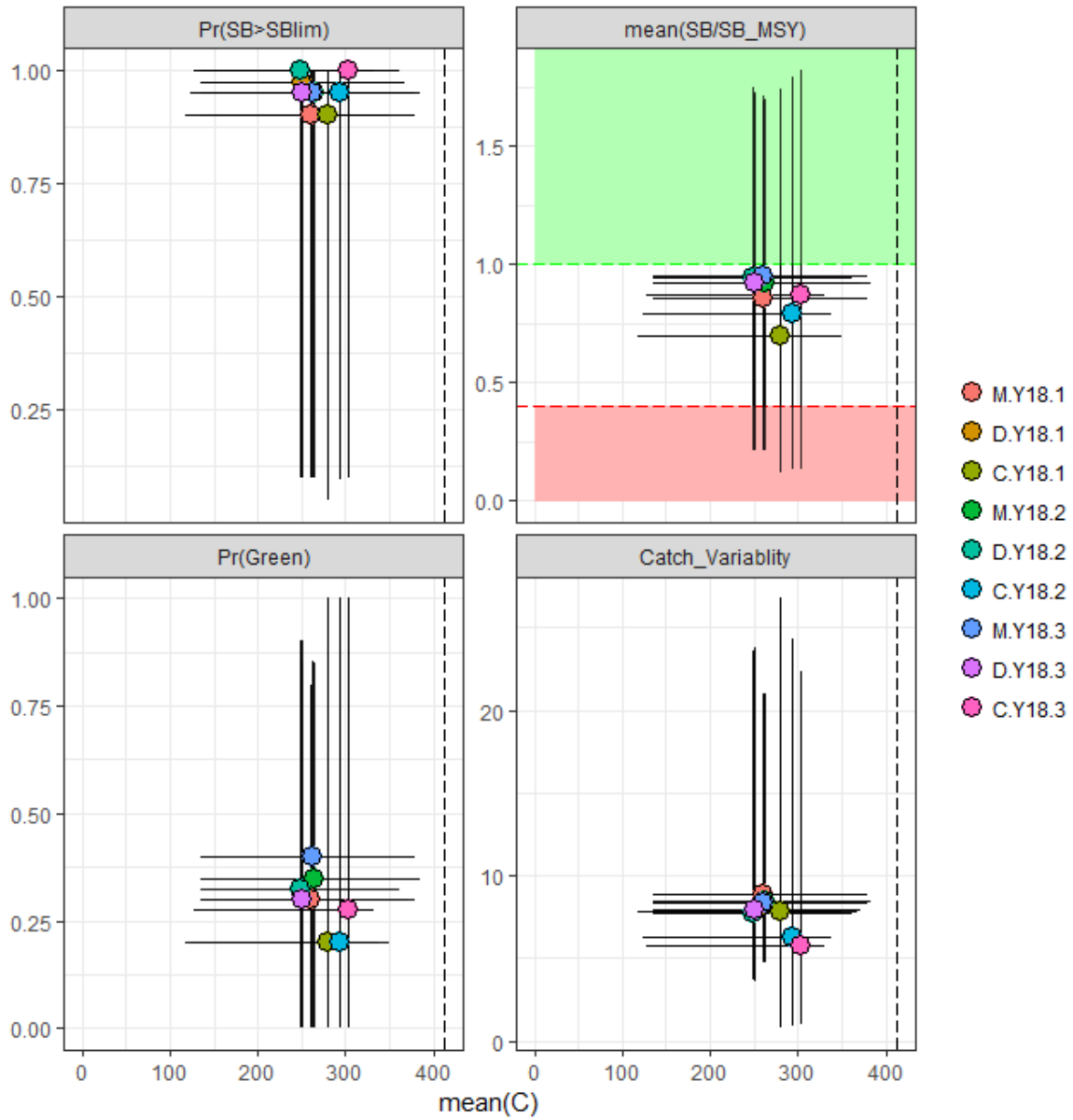
Figure 58. YFT reference case (OMrefY18.1) - Trade-off plots comparing a suite of model-based and data-based candidate MPs with respect to catch on the X-axis, and 4 other key performance measures on the Y-axis, each averaged over the period 2019 - 2038, tuning objective Y18.2 only. Circle is the median, lines represent 10th -90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB_{MSY} performance measure. The dashed vertical black line is 2016 catch.
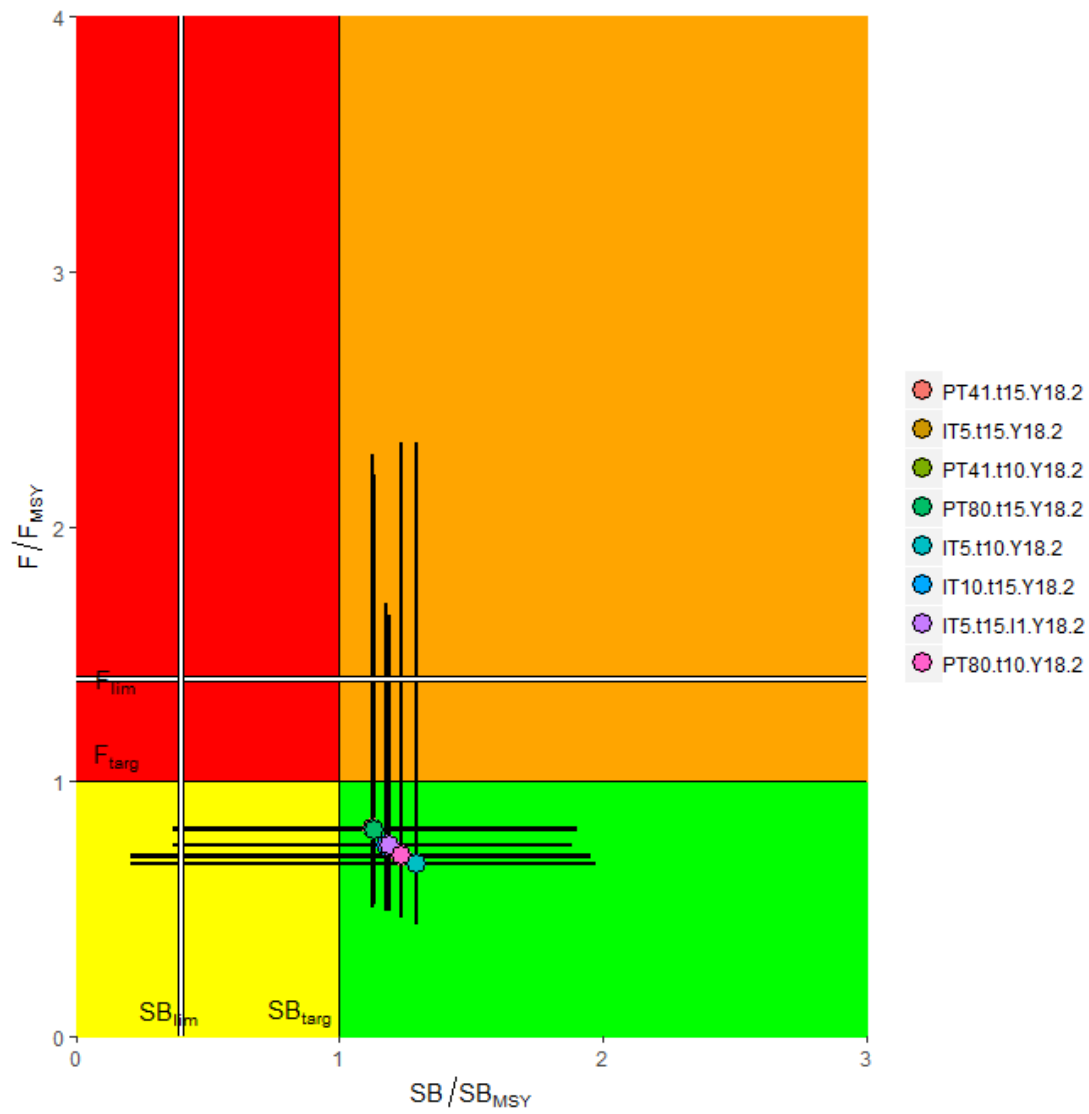
Figure 59. YFT reference case (OMrefY18.1) - Kobe plot comparing a suite of model-based and data-based candidate MPs on the basis of the expected 20 year average (2019-2038) performance, tuning objective Y18.2 only. Circle is the median, lines represent 10th-90th percentiles.
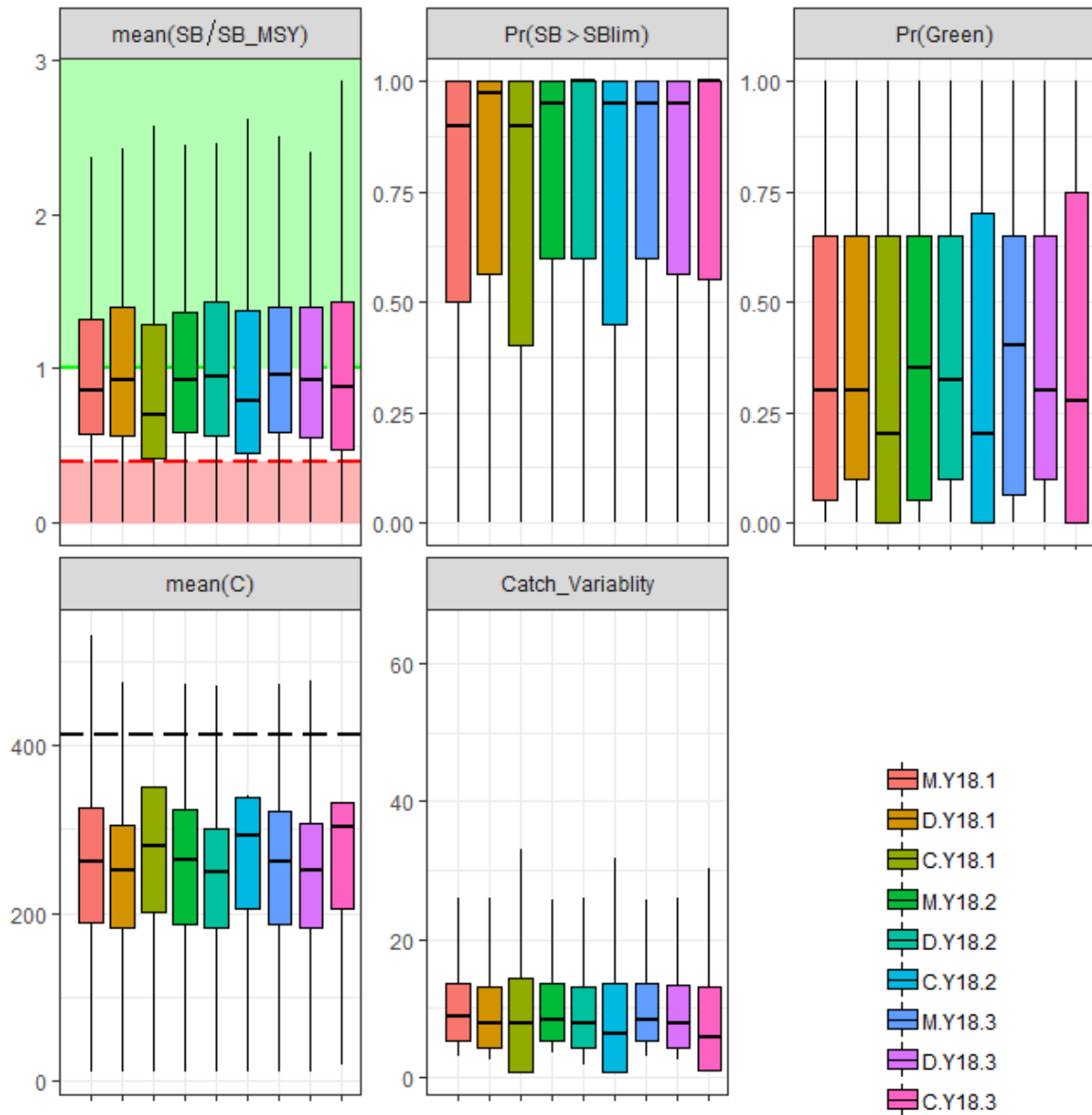
Figure 60. YFT robustness case (OMrobY18.1.recShock - recruitment failure) - Boxplots comparing candidate MPs with respect to key performance measures averaged over the period 2019 - 2038. Horizontal line is the median, boxes represent 25th - 75th percentiles, thin lines represent 10th - 90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB_{MSY} performance measure. The horizontal dashed black line is 2016 catch.

Figure 61. YFT robustness case (OMrobY18.1.recShock - recruitment failure) - Trade-off plots comparing candidate MPs with respect to catch on the X-axis, and 4 other key performance measures on the Y-axis, each averaged over the period 2019 - 2038. Circle is the median, lines represent 10th-90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB_{MSY} performance measure. The dashed vertical black line is 2016 catch.
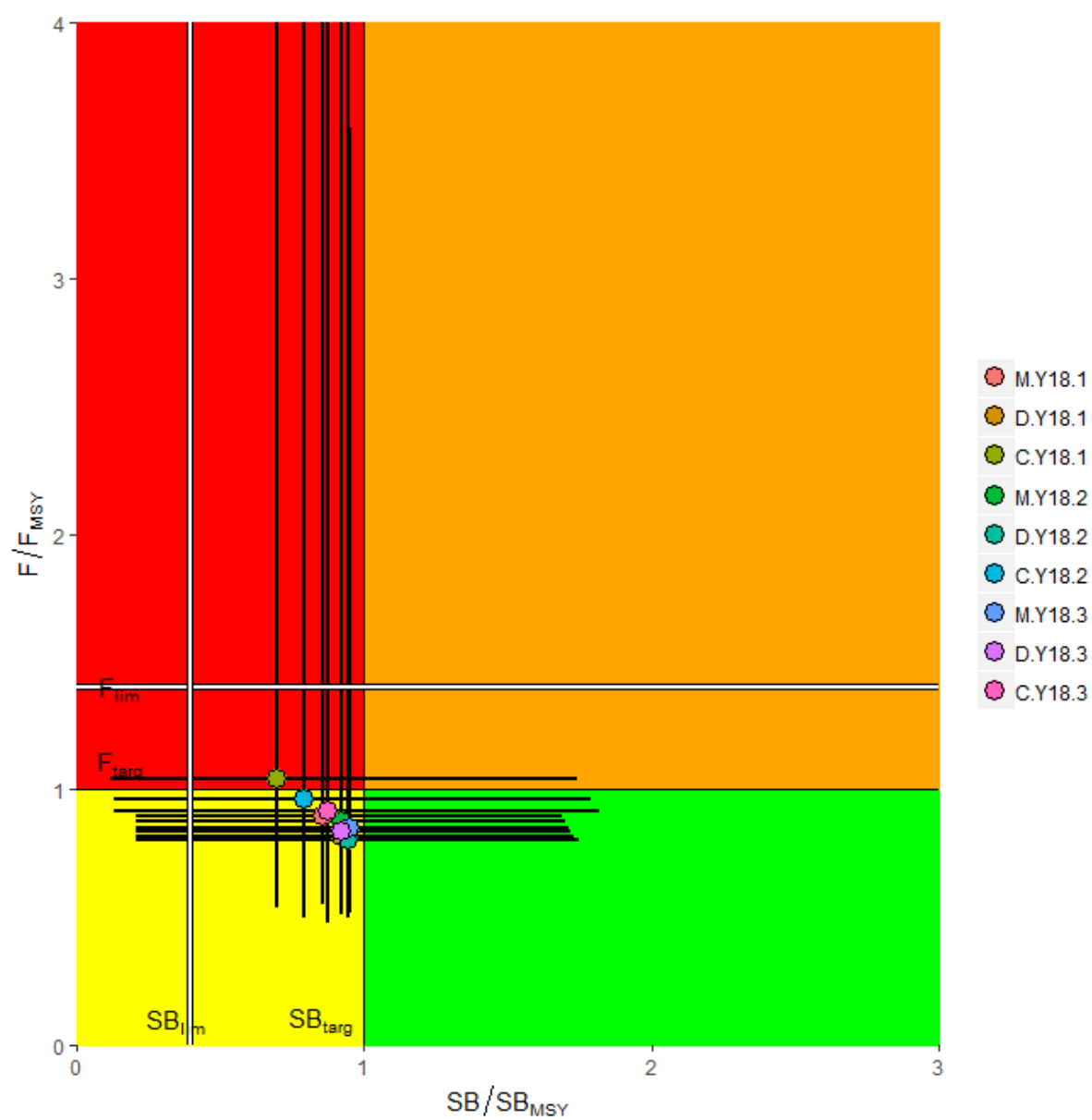
Figure 62. YFT robustness case (OMrobY18.1.recShock - recruitment failure) - Kobe plot comparing candidate MPs on the basis of the expected 20 year average (2019-2038) performance. Circle is the median, lines represent 10th-90th percentiles.
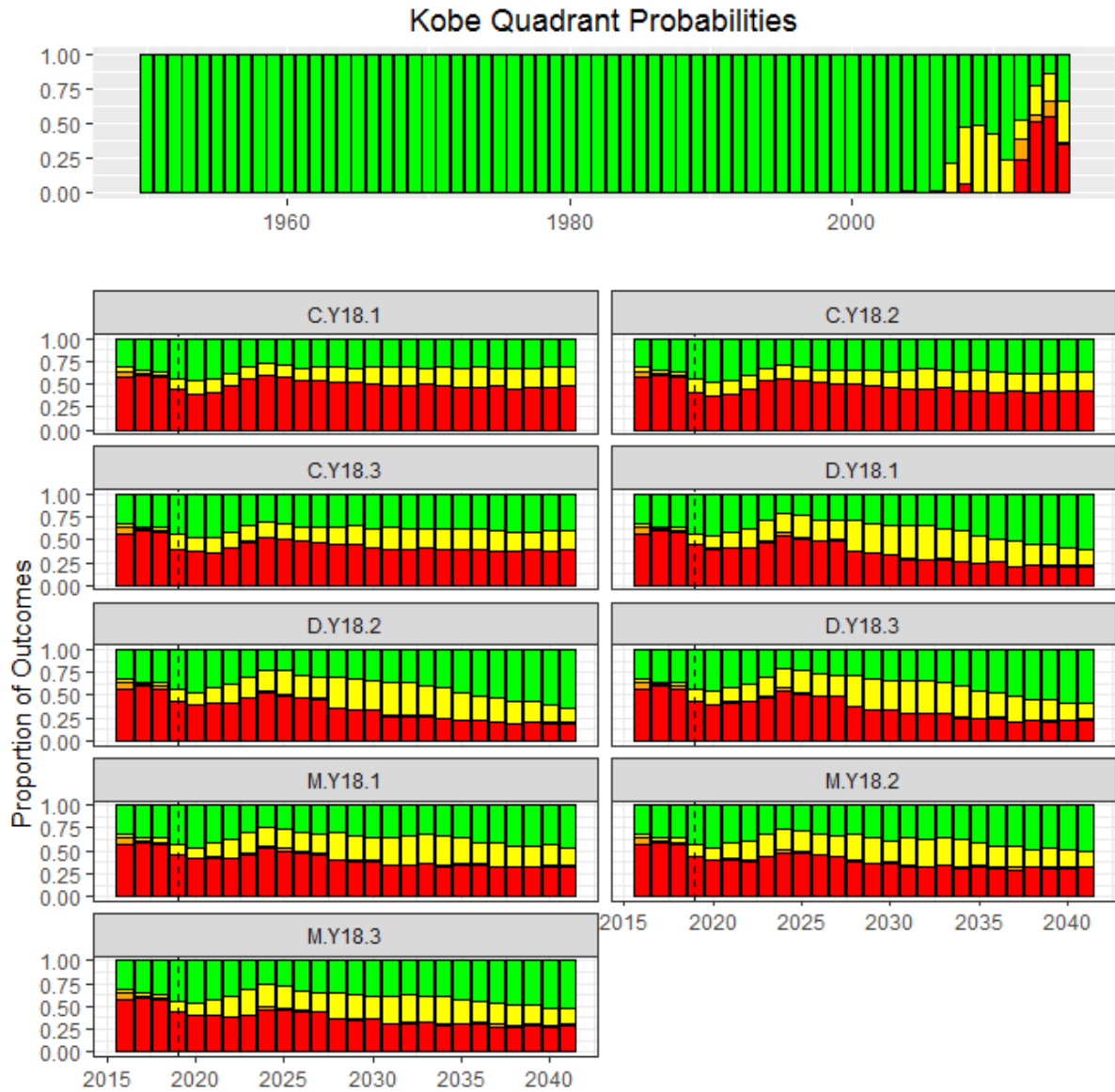
Figure 63. YFT rec robustness case (OMrobY18.1.recShock - recruitment failure) - Proportion of simulations in each of the Kobe quadrants over time for each of the candidate MPs. Historical estimates are included in the top panel. The lower panels are projections, with the first MP application indicated by the broken vertical line (2019).
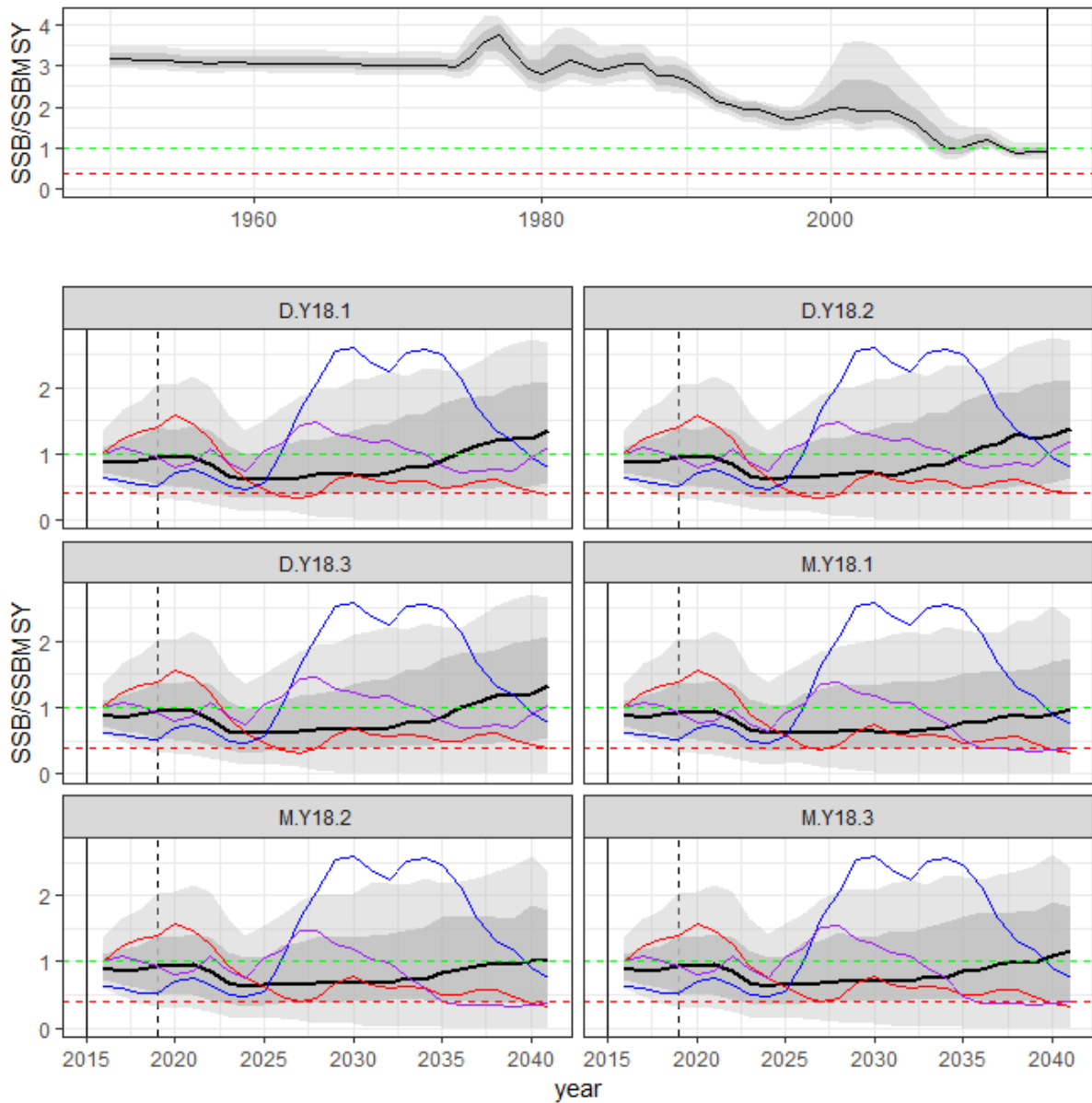
Figure 64. YFT rec robustness case (OMrobY18.1.recShock - recruitment failure) - Time series of spawning stock size for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
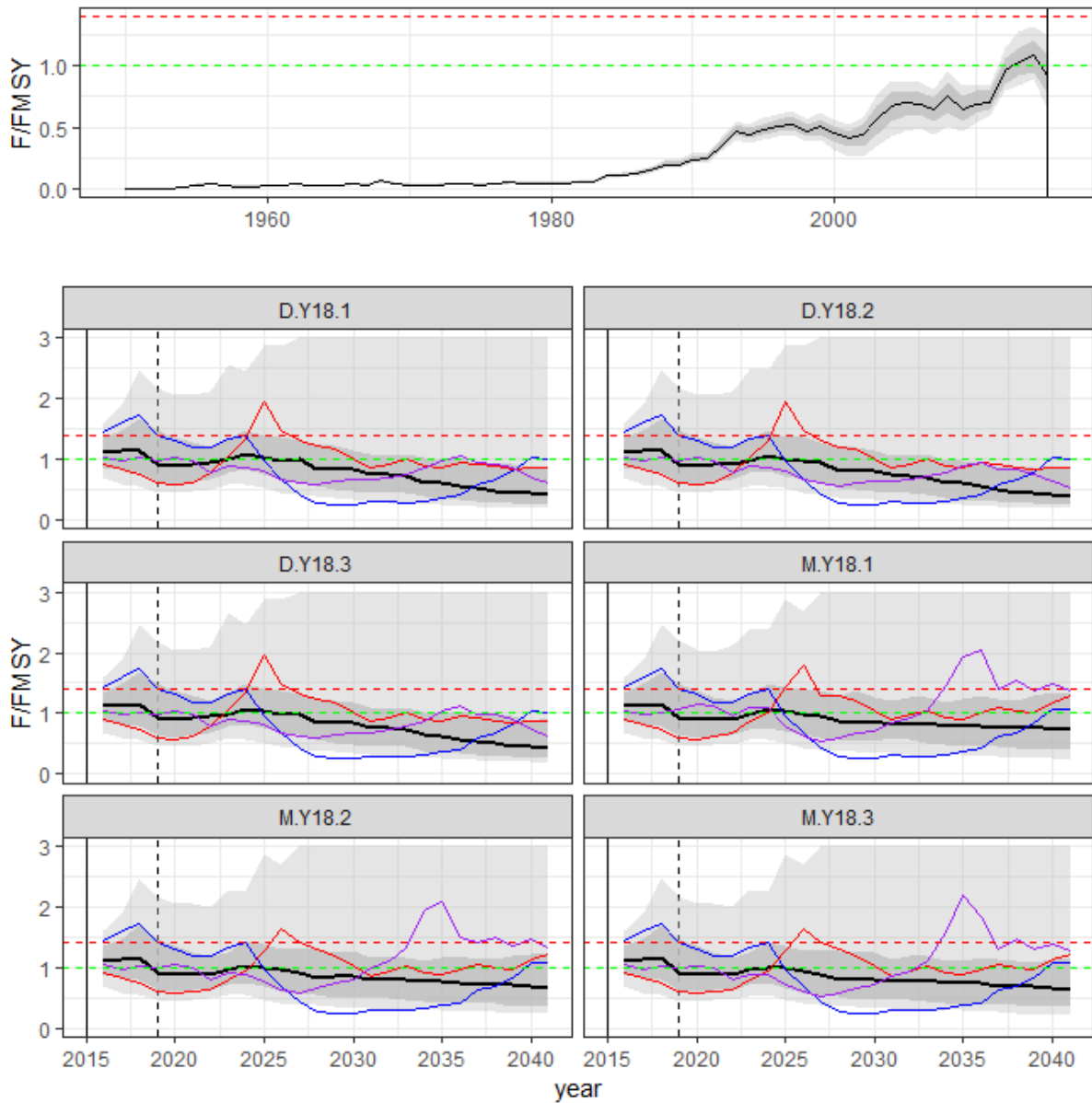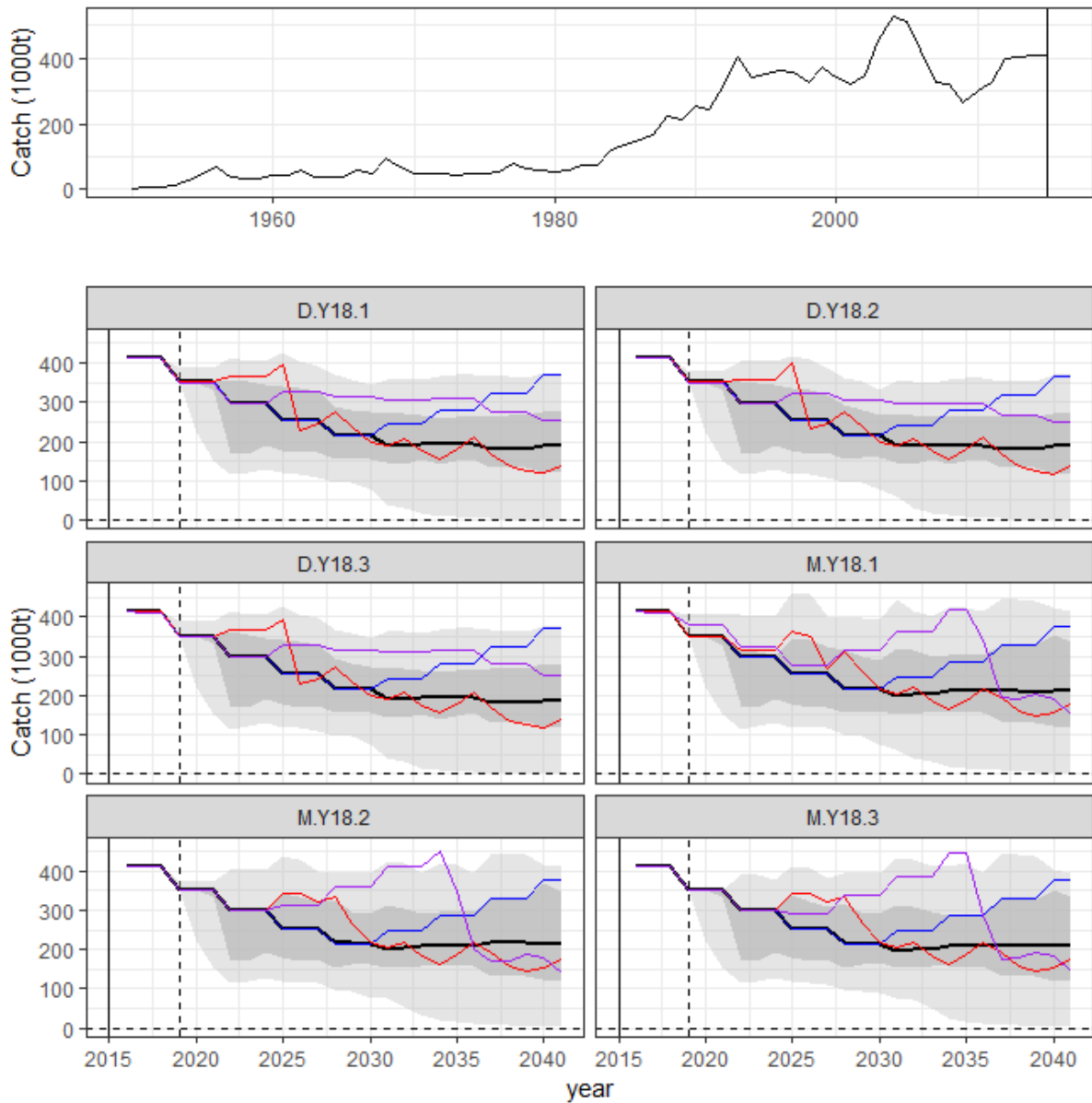
Figure 65. YFT rec robustness case (OMrobY18.1.recShock - recruitment failure) - Time series of fishing intensity (Upper bound truncated at F = 3) for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
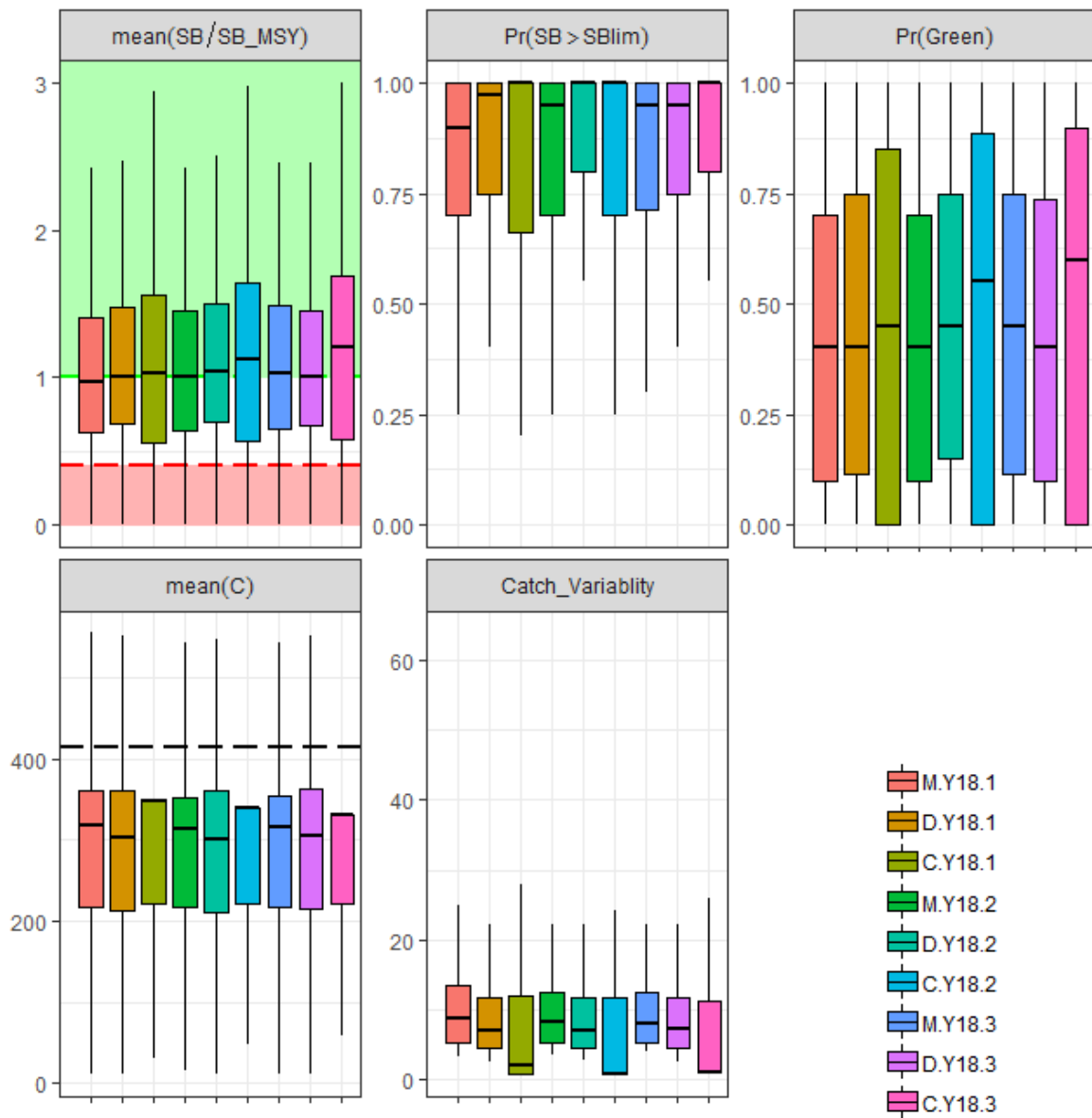
Figure 66. YFT rec robustness case (OMrobY18.1.recShock - recruitment failure) - Time series of catch for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. The broken black horizontal line represents recent (2016) catch. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
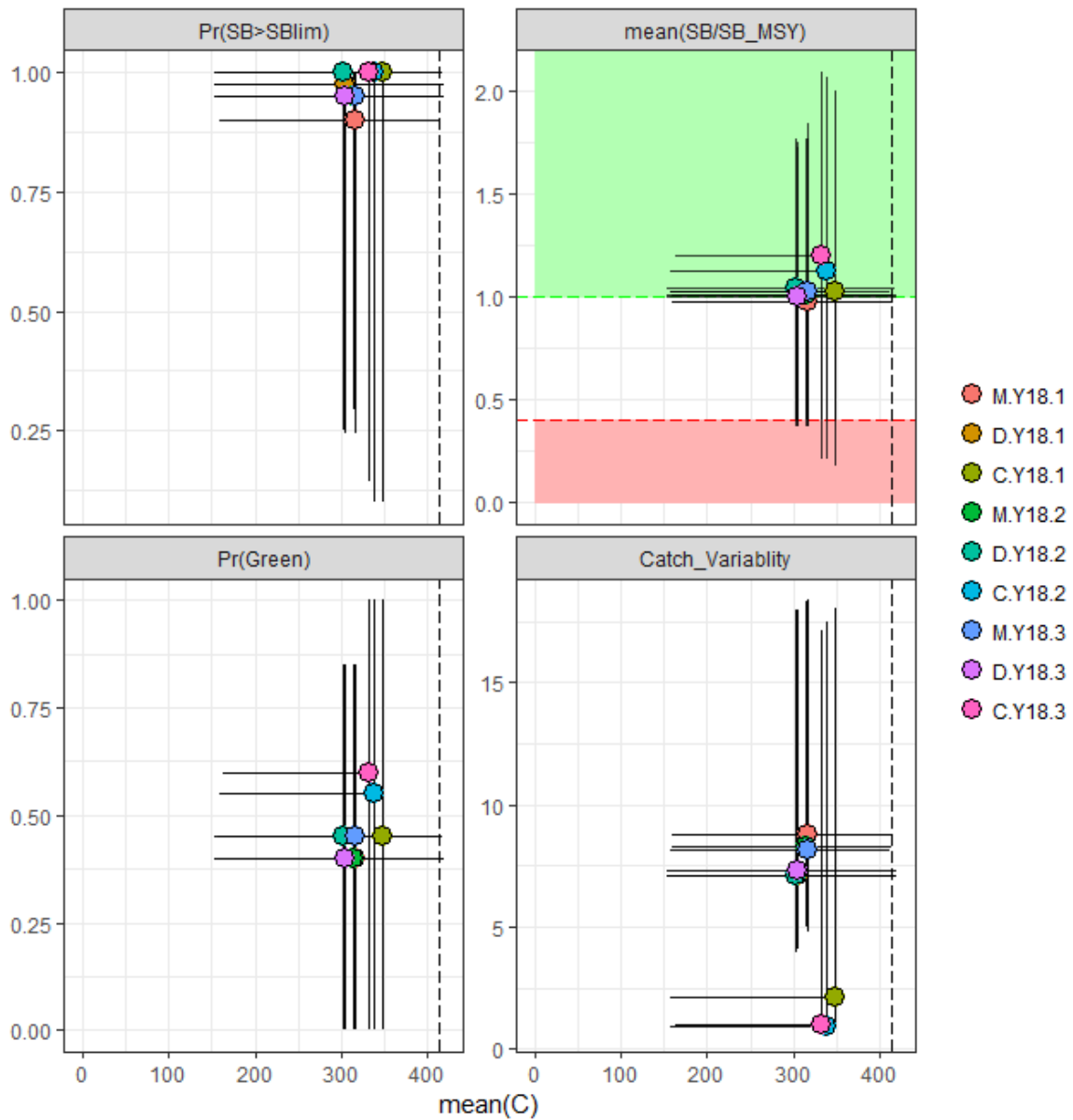
Figure 67. YFT robustness case (OMrobY18.1.qTrend3 - 3% per year catchability trend) - Boxplots comparing candidate MPs with respect to key performance measures averaged over the period 2019 - 2038. Horizontal line is the median, boxes represent 25th - 75th percentiles, thin lines represent 10th - 90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB$_{MSY}$ performance measure. The horizontal dashed black line is 2016 catch.

Figure 68. YFT robustness case (OMrobY18.1.qTrend3 - 3% per year catchability trend) - Trade-off plots comparing candidate MPs with respect to catch on the X-axis, and 4 other key performance measures on the Y-axis, each averaged over the period 2019 - 2038. Circle is the median, lines represent 10th-90th percentiles. Red and green horizontal lines represent the interim limit and target reference points for the mean SB/SB_{MSY} performance measure. The dashed vertical black line is 2016 catch.
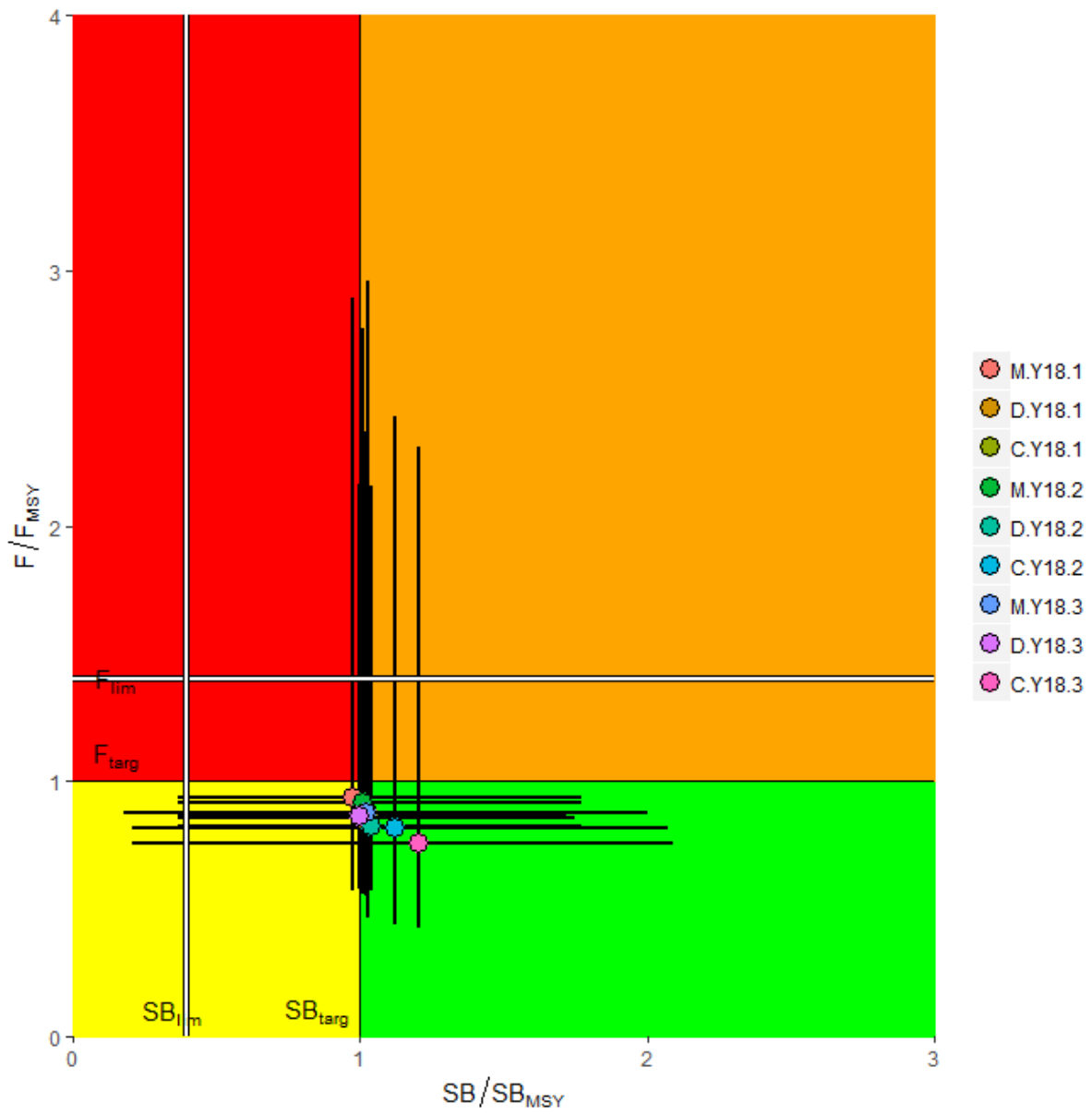
Figure 69. YFT robustness case (OMrobY18.1.qTrend3 - 3% per year catchability trend) - Kobe plot comparing candidate MPs on the basis of the expected 20 year average (2019-2038) performance. Circle is the median, lines represent 10th-90th percentiles.
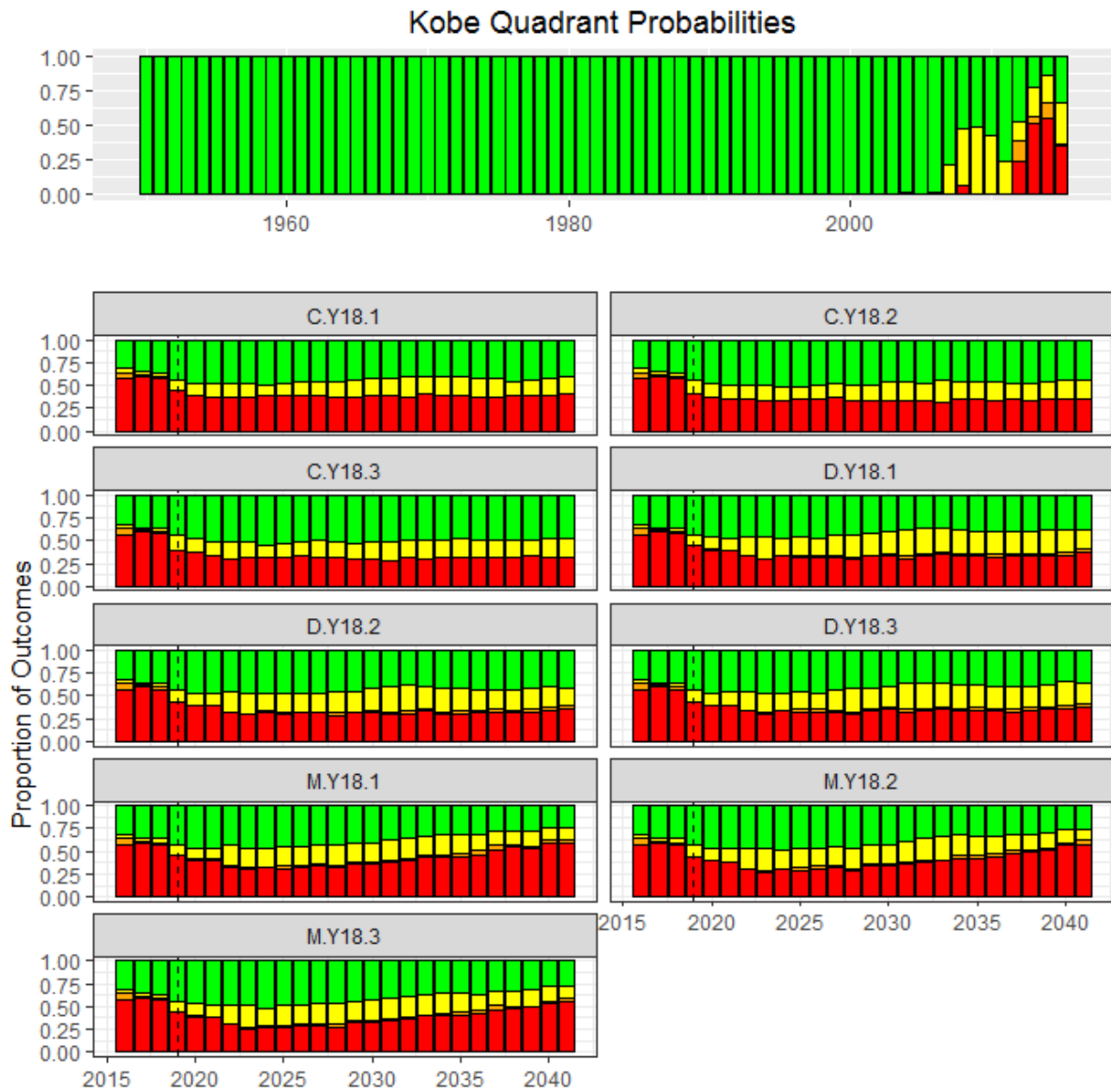
Figure 70. YFT rec robustness case (OMrobY18.1.qTrend3 - 3% per year catchability trend) - Proportion of simulations in each of the Kobe quadrants over time for each of the candidate MPs. Historical estimates are included in the top panel. The lower panels are projections, with the first MP application indicated by the broken vertical line (2019).
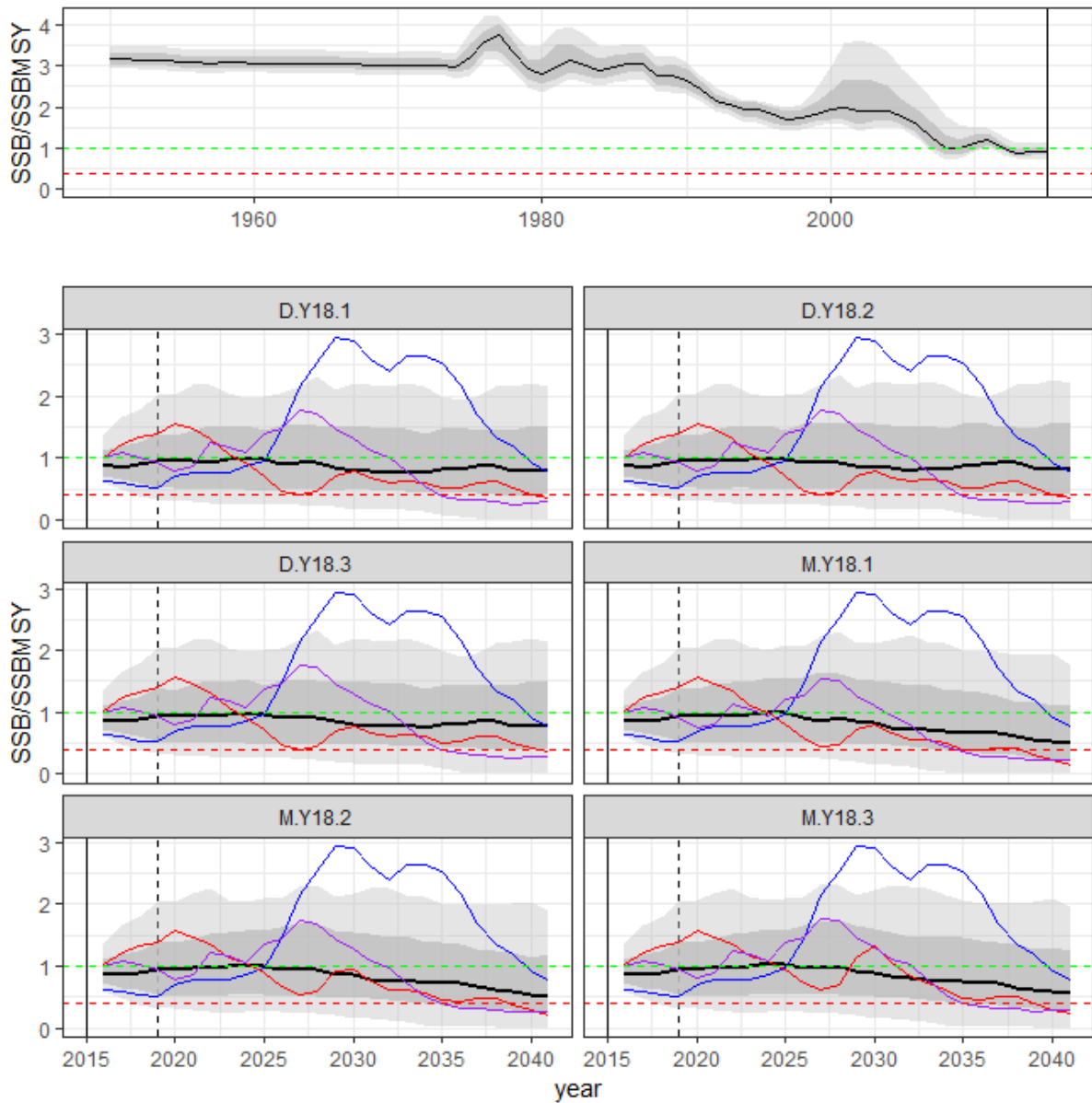
Figure 71. YFT rec robustness case (OMrobY18.1.qTrend3 - 3% per year catchability trend) - Time series of spawning stock size for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
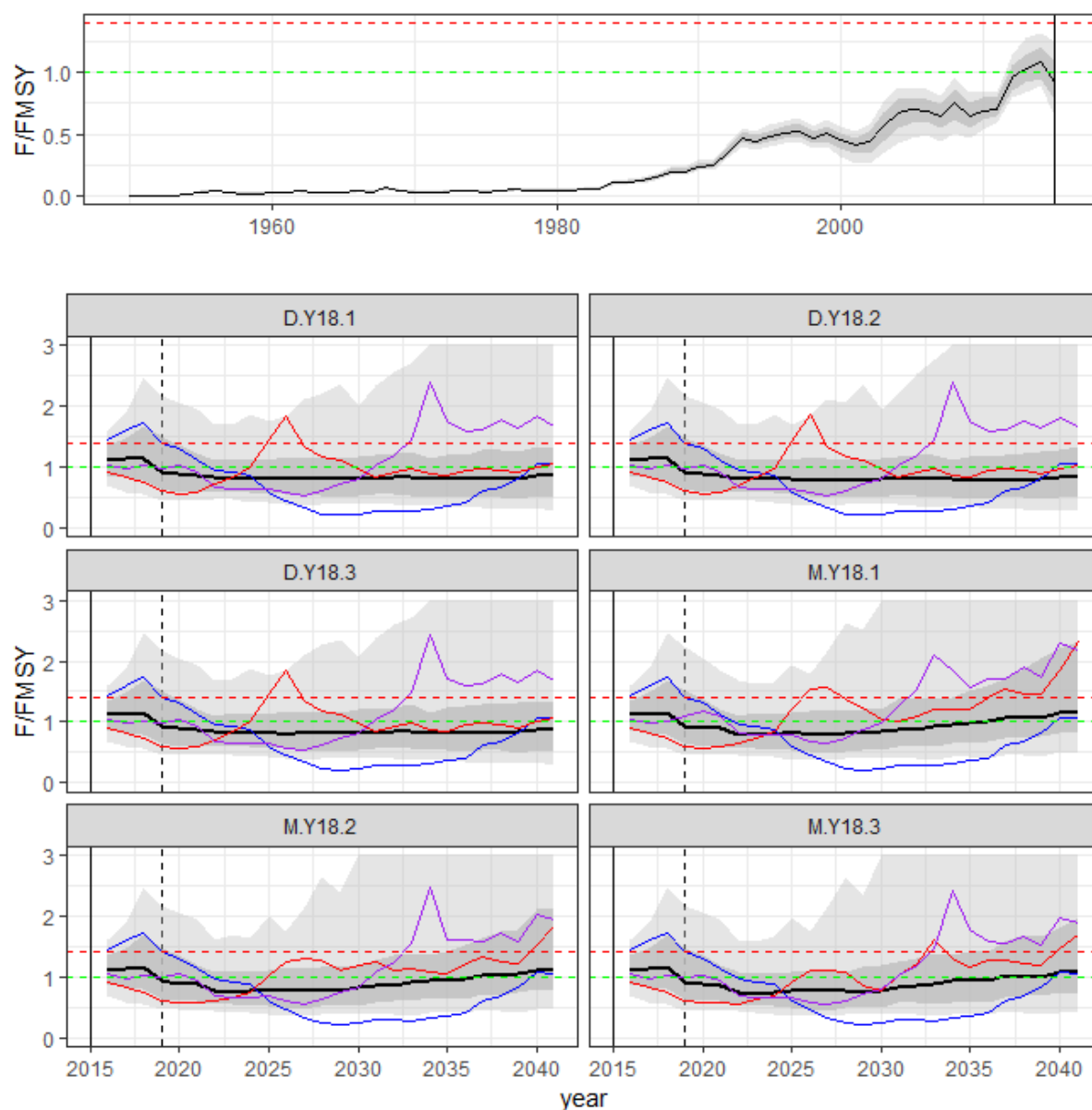
Figure 72. YFT rec robustness case (OMrobY18.1.qTrend3 - 3% per year catchability trend) - Time series of fishing intensity (Upper bound truncated at F = 3) for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. Thick broken lines represent the interim target (green) and limit (red) reference points. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.
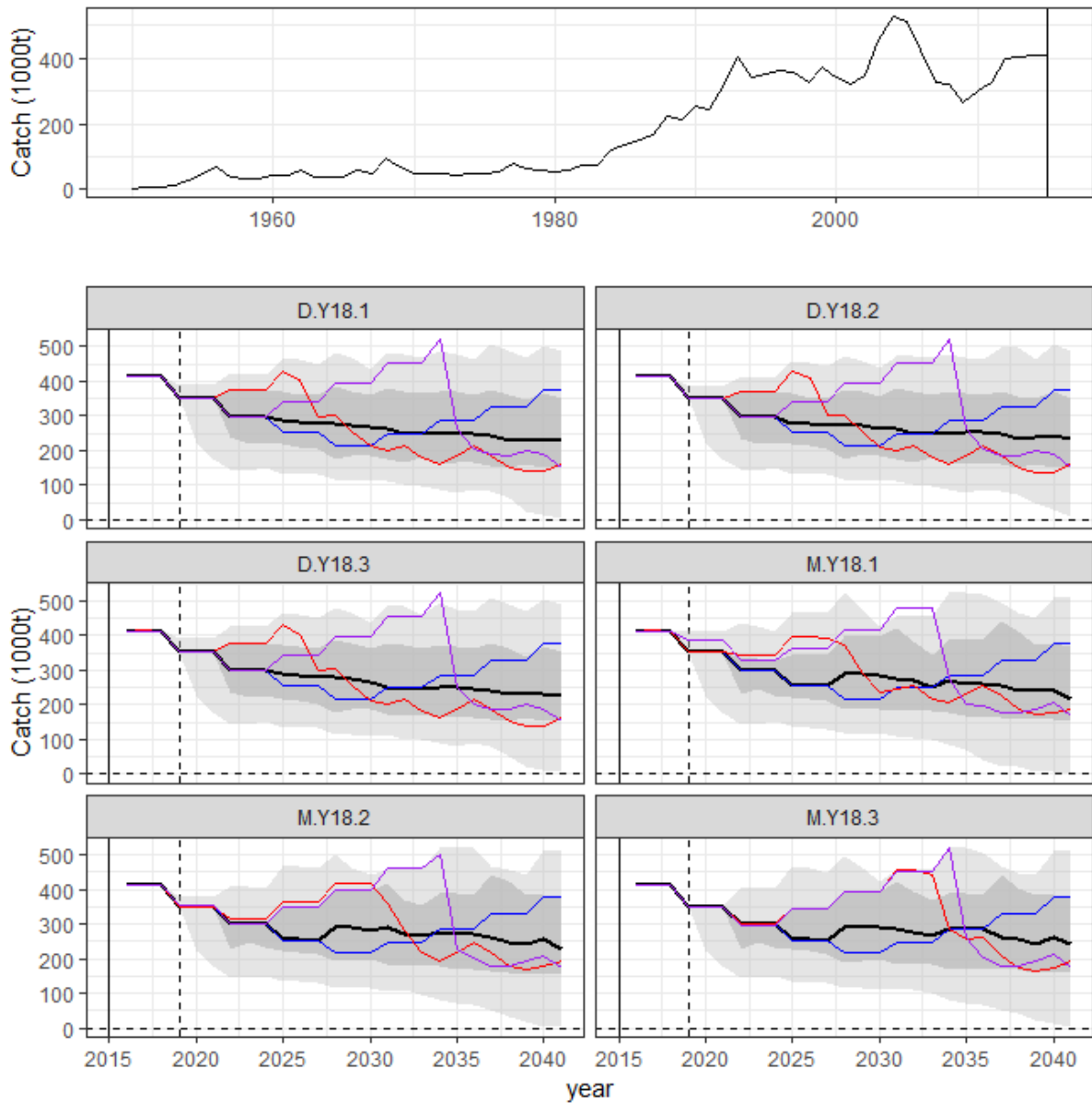
Figure 73. YFT rec robustness case (OMrobY18.1.qTrend3 - 3% per year catchability trend) - Time series of catch for the candidate MPs. The top panel represents the historical estimates from the reference case operating model, and lower plots represent the projection period. The solid vertical line represents the last year used in the historical conditioning. The broken vertical line represents the first year that the MP is applied. The median is represented by the bold black line, the dark shaded ribbon represents the 25th-75th percentiles, the light shaded ribbon represents the 10th-90th percentiles. The broken black horizontal line represents recent (2016) catch. The 3 thin coloured lines represent examples of individual realizations (the same OM scenarios across MPs and performance measures), to illustrate that individual variability greatly exceeds the median.

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