PA2_616/2022
11/11/2022 12:53
Original: English

ATLANTIC BLUEFIN TUNA MSE – FINAL RESULTS & DECISION GUIDE PACKAGE

Table of Contents

Introduction to the Decision Guide

This Decision Guide presents final results from the Atlantic bluefin tuna management strategy evaluation (MSE) and reflects decisions made at the Fourth Intersessional Meeting of Panel 2 on Bluefin Tuna MSE (Madrid, Spain, hybrid, 14 October 2022). It provides a step-by-step approach to facilitate discussion and decision-making for adoption of a final management procedure (MP) at the ICCAT Annual Meeting to be held 14-21 November 2022.

The SCRS has made substantial progress in testing candidate management procedures (CMPs) and considers the MSE to be complete except for exceptional circumstances provisions to be drafted in 2023. There are now two CMPs remaining, each with multiple variants, for consideration for adoption. Both CMPs meet Panel 2's guidance on minimum performance standards for stock status and safety; they also balance tradeoffs to maximize performance relative to the yield and stability objectives. They provide viable, robust options for setting total allowable catches (TACs) for Atlantic bluefin tuna in 2023 and beyond.

Candidate Management Procedures

Two types of candidate management procedures (**Table 1**) remain (BR and FO). All CMP types have the following characteristics:

- Each CMP is a 'package-deal' in that one single CMP calculates separate TACs for the West and East management areas.
- Both CMPs include a 'phase-in' period for both West and East management areas in which TAC changes are limited to a 20% increase and 10% decrease for two cycles for a 2-year setting or one cycle for a 3-year setting.
- They achieve a threshold safety objective of $LD^*_{15\%}$, meaning that there is no more than a 15% probability of the lowest depletion (LD) dropping below the limit reference point of 40% of dynamic SSB_{MSY} in projection years 11 through 30. LD* is the lowest value of spawning stock biomass (SSB) relative to dynamic SSB_{MSY} for each simulation during projection years 11 through 30.
- All results tested and presented here assume that the operational management objectives and other CMP specifications (e.g. management cycle length) are the same for both stocks/management areas.

Each of the two CMPs has twelve variants, performance tuned[1] to the probability of being in the green quadrant of a Kobe plot (PGK) performance statistic. All performance statistics are described in detail in **Table 2**. Note that there is no longer a variant for a 3-year management cycle with PGK60% and +20%/-30% stability because the combination of these two CMP options will not meet the minimum $LD^*_{15\%}$ threshold. Panel 2 removed it in October 2022 in favor of a variant that has a +20%/-35% stability provision.

Decision Guide Outline

There are several key decisions required for adoption of a final management procedure. Because there are only 24 variants remaining, the decisions can be made in a stepwise fashion, or a single variant can be chosen at once as a package. The remaining decisions are as follows:

1) Minimum TAC change: **Do** or **do not** require a minimum threshold for a TAC change before one occurs, of up to 100 t for the West management area and up to 1000 t for the East management area.
2) Operational management objective for Stock Status: **60%, 65%** or **70%** probability of occurring in the green quadrant ($SSB \geqq SSB_{MSY}$ & $U < U_{MSY}$) of the Kobe plot in year 30 of the projection period (PGK).
3) Management cycle length: **2**- or **3**-year TAC setting intervals.
4) Management procedure: **BR or FO**.

[1] Performance tuning is the process by which CMPs are adjusted to satisfy different minimum performance standards relative to PGK across the grid of operating models, while also achieving higher yield and stability objectives. All CMPs include at least one adjustable setting to determine how heavily or lightly it applies fishing pressure to achieve desired performance on the risk-reward tradeoff (i.e., catch vs. biomass) for each of the East area/eastern stock and West area/western stock, and this setting is adjusted during performance tuning.

Each decision point is addressed in individual sections of this document.

Presenting results

This package presents multiple performance tables called "quilt plots" (e.g. **Table 4**). The primary quilt plot presents five key statistics and associated percentiles, including PGK: probability of being in the Kobe green quadrant (i.e., $SSB \geqq SSB_{MSY}$ and $U \leq U_{MSY}$) in year 30; AvC10: average catch (kilotons, kt) over years 1-10 (50%ile); AvC30: average catch (kt) over years 1-30 (50%ile); VarC: Average variation in catch (% change from prior TAC) between management cycles (50%ile); $LD^*_{15\%}$: 15%tile of lowest depletion over years 11-30. These 5 top performance statistics were chosen on the basis of removing duplicative statistics and focusing on the four operational performance statistics of safety, status, yield, and stability.

To aid decision making, the SCRS provides a total score ("*Tot*") as a tool to rank CMPs to evaluate whether the relative ordering is conserved across the variants. Quilt plots use the default weighting scheme (i.e., 0 for PGK; 0.5 for AvC10 and AvC30; 1.0 for VarC and $LD^*_{15\%}$); though different weighting of management objectives resulted in nearly similar rankings of the four previously considered CMPs (SCRS/2022/169). PGK is not weighted in the scoring as all CMPs are tuned to a pre-specified PGK value (either 60%, 65% or 70%). Color scale represents relative performance from dark (best) to light (worst) within a column. CMPs are ordered relative to the total column (*Tot*), As with golf, a lower *Tot* score is better. *Tot* is calculated by scaling each column relative to the minimum to maximum range within that column, giving a rank order from 0 (best) to 1 (worst), weighting columns according to the default weighting, obtaining an average for West and East and then taking the average across East and West. Lower *Tot* values indicate better performance. Actual *Tot* values should be considered as qualitative rather than quantitative as they account only for order and not the magnitude of the change in the value of the performance statistic amongst the CMPs.

Other resources

Atlantic Bluefin Tuna MSE splash page, including interactive ShinyApp (ENG only)

- CMP Results and Plotting
- CMP Performance Overview with Quilt Plots
- CMP Performance with Spider Plot
- Mathematical specifications of BR and FO (see Annex 1 of PA2-613)
- Harveststrategies.org MSE outreach materials (multiple languages, including Arabic)

Table 1. Candidate Management Procedures (CMPs). All indices are referenced at the end of the table.

CMP	Indices used			Description
	EAST	WEST	Total	
BR Butterworth/ Rademeyer	All	All	10	Uses relative harvest rates compared to a reference year (2017), applied to the 3-year moving average of combined master abundance indices for East and for West.
FO Canada	FR_AER_SUV2 JPN_LL_NEAtl2 W_MED_LAR_SUV	US_RR_66_144 CAN_SWNS_RR MEXUS_LL	6	Uses a 3-year moving average of indices representative of young, medium and old fish to calculate an $F_{0.1}$ estimate which is applied to an estimate of biomass.

East indices: FR_AER_SUV2 – French aerial survey in the Mediterranean; JPN_LL_NEAtl2 – Japanese longline index in the Northeast Atlantic; W_MED_LAR_SUV – Larval survey in the western Mediterranean; MOR_POR_Trap – Moroccan-Portuguese trap index; GBYP_AER_SUV_BAR – GBYP aerial survey in the Balearics.

West indices: US_RR_66_144 – U.S. recreational rod & reel index for fish 66-144 cm; CAN_SWNS_RR – Canadian Southwest Nova Scotia handline index; MEXUS_LL – U.S. & Mexico combined longline index for the Gulf of Mexico; GOM_LAR_SUV – U.S. larval survey in the Gulf of Mexico; JPN_LL_West2 - Japanese longline index for the West Atlantic.

Table 2. Table of Operational Management Objectives and Performance Statistics. Performance statistics are calculated based on 48 simulations/replicates for each of the 48 operating models of a 30-year projection under a CMP. Results reported are percentiles of the resultant distributions, e.g. median (50%-ile) or lower 5%-ile.

Management Objectives (Res. 18-03) + PA2 guidance	**Primary Performance Statistics (Quilt plot 1)**	**Secondary Performance Statistics (Quilt plot 2)**
Status The stock should have a greater than [60][65][70]% probability of occurring in the green quadrant of the Kobe matrix. (To be evaluated at intermediate points between zero and 30 years, and at the end of the 30-year period.)	**PGK**: Probability of being in the Kobe green quadrant (i.e., SSB≧dynamic SSB_{MSY}[1] and U<U_{MSY}[2]) in year 30 of the management period (2052).	**Br30** – Br [i.e., biomass ratio, or spawning stock biomass (SSB) relative to dynamic SSB_{MSY}] after 30 years. **AvgBr** – Average Br over projection years 11-30. **Br20** – Br after 20 years. **POF** – Probability of overfishing (U>U_{MSY}) after 30 projected years. **PNRK** – Probability of not being in the red Kobe quadrant (SSB ≧ SSB_{MSY} and/or U < U_{MSY}) after 30 projected years. **OFT** – Overfished Trend, SSB trend if Br30<1.
Safety There should be no more than a 15% probability of the stock falling below B_{LIM} at any point during the years 11-30 of the projection period.	**LD*** – Lowest depletion (i.e., the lowest SSB relative to dynamic SSB_{MSY}) over years 11-30 in the projection period. LD* value is evaluated relative to B_{LIM} (40% of dynamic SSB_{MSY}). $LD^*_{5\%}$, $LD^*_{10\%}$ and $LD^*_{15\%}$ are all evaluated, with the latter in Quilt 1 and the former 2 in Quilt 2.	
Yield Maximize overall catch levels.	**AvC10** – Median TAC (t) over years 1-10. **AvC30** – Median TAC (t) over years 1-30.	**C1** – TAC in first 2 or 3 years of MP (i.e., 2023-24 or 2023-25), depending on management cycle length. **AvC20** – Median TAC (t) over years 1-20.
Stability Any change in TAC between management periods should be no more than a 20% increase or a [30][35]% decrease, except during the application of the MP in the first (for 3-year cycle) or two management periods (for 2-year cycle), where any TAC change shall not exceed a 20% increase or a 10% decrease.	**VarC** – Variation in TAC (%) between management cycles (2 or 3 year).	

[1]Dynamic SSB_{MSY} is a set fraction of dynamic SSB_0, which is the spawning stock biomass that would occur in the absence of fishing, historically and in the future. Dynamic SSB_{MSY} can change over time since it is based on current recruitment levels, which fluctuate due to time-varying dynamics in the models.

[2]The exploitation rate (U) is annual catch (in tonnes) divided by the total annual biomass in tonnes. U_{MSY} is the fixed harvest rate (U) corresponding with SSB/SSB_{MSY}=1 at year 50.

Decision Point #1: Minimum TAC change

Options: Do or **do not** adopt a required minimum TAC change threshold from one management cycle to the next. **If adopted**, specify a minimum TAC change of **up to 100 t for the West** management area and **up to 1000 t for the East** management area.

Strategic considerations:

- Specifying a minimum change in TAC could help to ease administrative burden because MP-determined TAC increases and decreases of less than the minimum level would be disregarded, eliminating the need for management change at the ICCAT and CPC level.
- The addition of a 100t-West and 1000t-East minimum TAC threshold had very minor impacts to the performance statistics.
- Because of this minor impact, the remaining results for Decision points #2-4 incorporate a minimum TAC change threshold of 100 t for the West and 1000 t for the East.
- Because 100 t and 1000 t were shown to have very minor impact, any lower values (e.g. within the ranges 0-99 t and 0-999 t) would be similar and are thus viable options.

Relevant results:

Individual CMP results with and without the threshold are available in the quilt plot referenced under Decision Point 4 (**Table 11**). Only the results averaged across CMPs, PGK targets and 2 and 3-year variants are shown here to illustrate the very minor differences resulting from implementing this minimum requirement for TAC changes (**Table 3**).

Table 3. Averaged over all CMPs, PGK targets and 2 and 3-year variants, the percentage difference in all primary performance statistics is quite low, except for VarC, which is higher with the minimum threshold. This is not unexpected given that, when a change in TAC is made, such change needs to be greater with the 100/1000 t thresholds.

	PGK (Mean)	AvC10 (50%)	AvC30 (50%)	VarC (50%)	LD (15%)	PGK (Mean)	AvC10 (50%)	AvC30 (50%)	VarC (50%)	LD (15%)
no min	0.66	2.65	2.38	12.69	0.42	0.65	46.30	37.65	17.23	0.454
100/1000t minimum threshold	0.66	2.66	2.38	13.44	0.42	0.65	46.29	37.64	17.56	0.455
% difference	0.4%	0.2%	0.2%	5.9%	0.0%	0.3%	0.0%	0.0%	1.9%	0.2%

Decision Point #2: Operational management objective for Stock Status

Options: 60%, 65% or **70%** probability of PGK. PGK stands for Probability Green Kobe. It is the probability of being in the Kobe green quadrant (i.e. SSB≧dynamic SSB_{MSY} and U<U_{MSY}) in year 30 of the projection period (i.e., 2052).

***Strategic considerations*:**

- PGK of 60% (heavier fishing pressure) entails a higher probability of overfishing and/or of being overfished, but delivers greater catches, relative to PGK 70% (lower fishing pressure).

Relevant results:

The two CMPs were tuned to a minimum of PGK=60%, PGK=65% and PGK=70%, using 2 and 3-year management cycles (**Tables 4, 5, 6** and **Figure 1**). PGK65% is half-way between PGK60 and PGK70% on short and long-term yield for both FO and BR, showing a roughly linear relationship among PGK levels and catch (**Figure 1**).

Table 4. Primary quilt plot for the West and East, with CMPs tuned to **PGK=60%, PGK=65%** and **PGK=70%.** All results assume a **2-year management cycle**, 100 t/1000 t minimum TAC change, and +20/-30 stability following the initial 4-year phase-in period. See "Presenting results" on page 3 for a description of quilt plots. CMPs are ordered within a 'Type' by the '*Tot*' column to indicate relative ranking within a CMP.

		West					East					
CMP	PGK	PGK Mean)	AvC10 (50%)	AvC30 (50%)	VarC (50%)	LD (15%)	PGK (Mean)	AvC10 (50%)	AvC30 (50%)	VarC (50%)	LD (15%)	Tot
BR	70%	0.71	2.59	2.2	9.61	0.45	0.71	46.43	38.08	15.18	0.51	0.29
BR	65%	0.65	2.69	2.33	9.7	0.44	0.66	49.27	39.72	15.57	0.48	0.33
BR	60%	0.6	2.77	2.44	10	0.42	0.6	51.97	41.33	15.98	0.45	0.41
FO	65%	0.66	2.78	2.5	15.3	0.41	0.65	44.95	35.44	17.02	0.49	0.71
FO	70%	0.72	2.67	2.37	15.47	0.41	0.7	42.65	33.51	16.71	0.53	0.71
FO	60%	0.62	2.88	2.59	15.09	0.4	0.6	46.85	37.14	17.08	0.45	0.75

Table 5. Primary quilt plot for the West and East, with CMPs tuned to **PGK=60%, PGK=65%** and **PGK=70%.** All results assume a **3-year management cycle** and 100 t/1000 t minimum TAC change. CMPs tuned to PGK65% and PGK70% use +20/-30 stability following the phase-in, while PGK60% uses +20/-35 stability following the initial 3-year phase-in period. See "Presenting results" on page 3 for a description of quilt plots. CMPs are ordered within a 'Type' by the '*Tot*' column to indicate relative ranking within a CMP.

		West					East					
CMP	PGK	lean)	AvC10 (50%)	AvC30 (50%)	VarC (50%)	LD (15%)	PGK (Mean)	AvC10 (50%)	AvC30 (50%)	VarC (50%)	LD (15%)	Tot
BR	70%	0.7	2.57	2.19	10.97	0.43	0.7	43.29	37.28	17.57	0.44	0.33
BR	60%	0.6	2.74	2.46	11.07	0.4	0.6	48.41	41.28	19.23	0.41	0.46
BR	65%	0.66	2.64	2.3	11.02	0.41	0.65	45.65	39.17	17.98	0.41	0.46
FO	70%	0.71	2.43	2.3	17.8	0.42	0.7	43.12	34.45	19.11	0.46	0.63
FO	60%	0.63	2.59	2.51	17.78	0.42	0.62	47.15	37.73	19.98	0.41	0.66
FO	65%	0.66	2.53	2.41	17.47	0.41	0.65	45.71	36.58	19.26	0.42	0.7

Table 6. Performance statistics averaged across the two CMP types and the 2 and 3 yr management cycles for PGK 60%, PGK 65%, and PGK 70%, with and without a minimum TAC change. All variants use +20%/-30% stability, with the exception of PGK 60% with a 3-year management cycle, which uses a +20%/-35% stability. By averaging across all CMP variants, this table isolates the key trade-offs for the PGK decision.

	West				**East**			
	AvC10 (50%)	**AvC30 (50%)**	**VarC (50%)**	**LD* (15%)**	**AvC10 (50%)**	**AvC30 (50%)**	**VarC (50%)**	**LD* (15%)**
PGK 60%	2.75	2.50	13.18	0.41	48.59	39.39	17.88	0.43
PGK 65%	2.66	2.38	12.99	0.42	46.41	37.73	17.30	0.45
PGK 70%	2.56	2.26	13.01	0.43	43.88	35.82	16.99	0.48
% difference from PGK60 to 70	-7%	-9%	-1%	4%	-10%	-9%	-5%	13%

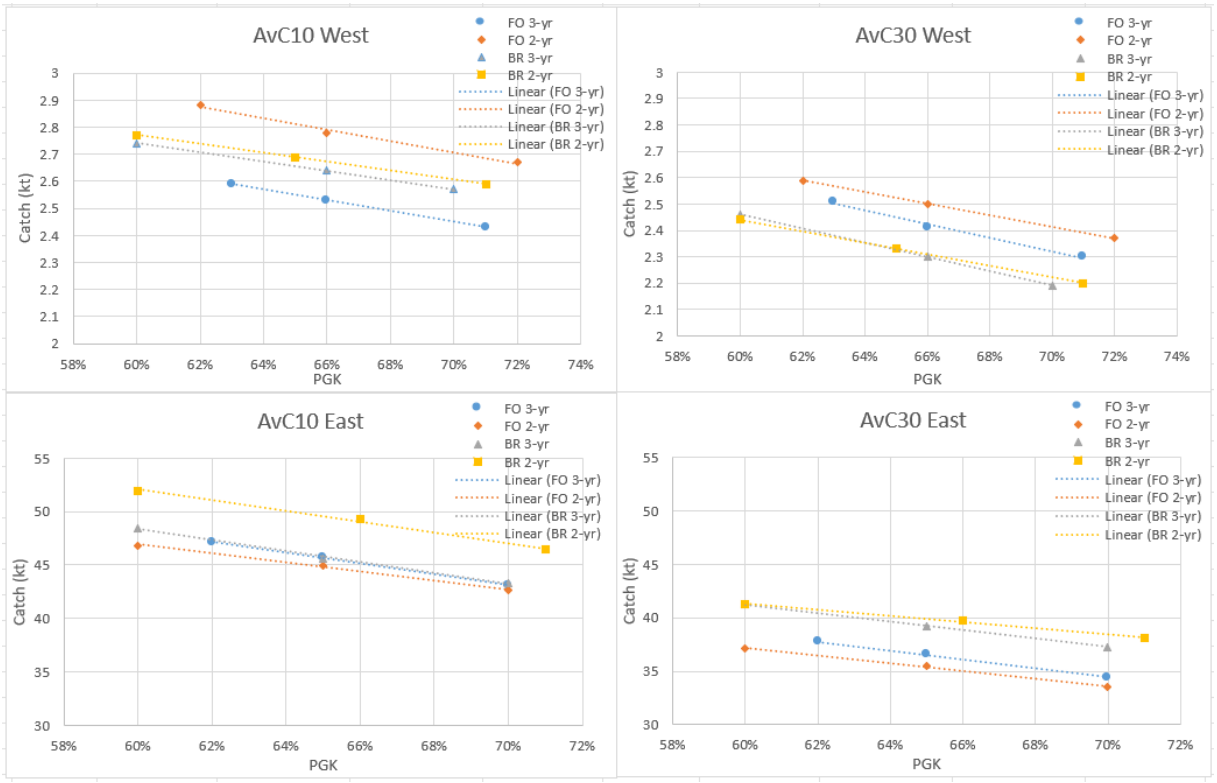


Figure 1. Performance results of the BR and FO CMPs, with 2- or 3-year management cycles, showing the nearly linear relationship between PGK values and catch. Short-term catch (AvC10) is on the left, and long-term catch (AvC30) is on the right. The West management area is on the top, and the East management area is on the bottom. All CMPs use the 100 t (West) and 1000 t (East) minimum thresholds for TAC change.

Decision Point #3: Management cycle length

Options: 2-or **3**-year TAC setting intervals. That is, the first TAC would apply for either 2023-2024 or 2023-2025, depending upon which management cycle is chosen.

Strategic considerations:

- The 3-year cycle CMPs are slightly slower to react to signals to change the TAC. As a result, the changes in TAC need to be larger in the 3-year cycle variants, and this is seen in larger VarC statistics.
- Managers will need to decide whether biomass and yield differences, which differ by CMP type, as shown below, are large enough to outweigh other considerations, such as administrative needs.

Relevant results:

Two- and 3-year management cycles were tested for the two CMPs across PGK 60%, PGK 65% and 70% (**Table 7, 8, 9, 10**).

Table 7. Primary quilt plot for **PGK=60%.** Results are shown for **2-year** and **3-year management cycles**. Two-year variants use +20/-30 stability following the phase-in, while 3-year variants use +20/-35 stability. All variants use 100t/1000t minimum TAC change thresholds.

		West					East					
CMP	Mgmt cycle	GK an)	AvC10 (50%)	AvC30 (50%)	VarC (50%)	LD (15%)	PGK (Mean)	AvC10 (50%)	AvC30 (50%)	VarC (50%)	LD (15%)	Tot
BR	2-yr	0.6	2.77	2.44	10	0.42	0.6	51.97	41.33	15.98	0.45	0.11
FO	2-yr	0.62	2.88	2.59	15.09	0.4	0.6	46.85	37.14	17.08	0.45	0.49
BR	3-yr	0.6	2.74	2.46	11.07	0.4	0.6	48.41	41.28	19.23	0.41	0.66
FO	3-yr	0.63	2.59	2.51	17.78	0.42	0.62	47.15	37.73	19.98	0.41	0.78

Table 8. Primary quilt plot for **PGK=65%.** Results are shown for **2-year** and **3-year management cycles**. All variants use +20/-30 stability following the phase-in and 100 t/1000 t minimum TAC change thresholds.

		West					East					
CMP	Mgmt cycle	PGK (Mean)	AvC10 (50%)	AvC30 (50%)	VarC (50%)	LD (15%)	PGK (Mean)	AvC10 (50%)	AvC30 (50%)	VarC (50%)	LD (15%)	Tot
BR	2-yr	0.65	2.69	2.33	9.7	0.44	0.66	49.27	39.72	15.57	0.48	0.12
FO	2-yr	0.66	2.78	2.5	15.3	0.41	0.65	44.95	35.44	17.02	0.49	0.52
BR	3-yr	0.66	2.64	2.3	11.02	0.41	0.65	45.65	39.17	17.98	0.41	0.68
FO	3-yr	0.66	2.53	2.41	17.47	0.41	0.65	45.71	36.58	19.26	0.42	0.9

Table 9. Primary quilt plot for **PGK=70%.** Results are shown for **2-year** and **3-year management cycles**. All variants use +20/-30 stability following the phase-in and 100 t/1000 t minimum TAC change thresholds.

		West					East					
CMP	Mgmt cycle	PGK (Mean)	AvC10 (50%)	AvC30 (50%)	VarC (50%)	LD (15%)	PGK (Mean)	AvC10 (50%)	AvC30 (50%)	VarC (50%)	LD (15%)	Tot
BR	2-yr	0.71	2.59	2.2	9.61	0.45	0.71	46.43	38.08	15.18	0.51	0.14
FO	2-yr	0.72	2.67	2.37	15.47	0.41	0.7	42.65	33.51	16.71	0.53	0.52
BR	3-yr	0.7	2.57	2.19	10.97	0.43	0.7	43.29	37.28	17.57	0.44	0.58
FO	3-yr	0.71	2.43	2.3	17.8	0.42	0.7	43.12	34.45	19.11	0.46	0.84

Table 10. Performance statistics averaged across 2 CMP types and PGK 60%, 65% and 70% for 2 and 3-year management cycles, with the default stability of +20%/-30% or +20/-35% for PGK60% and 3-year cycle. The percent difference row is shown relative to a 2-year cycle (i.e., the West AvC10 of -5.3% means that a 3-year management cycle has 5.3% lower short-term catch than a 2-year cycle). By averaging across all CMP variants, this table isolates the 2 vs. 3-year decision. The rank order of CMPs is retained across 2 versus 3 years.

	West				**East**			
Mgmt cycle (yrs)	**AvC10 (50%)**	**AvC30 (50%)**	**VarC (50%)**	**LD* (15%)**	**AvC10 (50%)**	**AvC30 (50%)**	**VarC (50%)**	**LD* (15%)**
2-year	2.73	2.41	11.85	0.42	47.43	37.92	16.01	0.48
3-year	2.58	2.36	14.01	0.42	45.55	37.74	18.73	0.43
% difference	-6%	-2%	18%	-1%	-4%	0%	17%	-12%

Decision Point #4: Management procedure type

Options: ***BR*** *or* ***FO***

Strategic considerations:

- There are 24 remaining CMP variants – BR and FO tuned to 60%, 65% and 70% PGK, using 2 and 3-year management cycles, and with and without a minimum threshold for TAC change (**Tables 11, 12, 13**).
- Each CMP uses a different combination (or all) of the abundance indices.
- Both CMPs meet minimum operational management objectives for Stock Status and Safety but with varying performance on the Yield and Stability tradeoffs.

Relevant results:

Primary quilt plots are shown in the preceding sections to show relative performance of the two remaining CMPs (**BR** and **FO**), across the various PGK (**Tables 4, 5**) and management cycle length (**Tables 7, 8, 9**) variants. These are ranked on 4 key performance statistics for both East and West (**Table 11**). A secondary quilt plot (**Table 12**) includes 10 additional statistics. Short- and long-term yields for the remaining CMP types are shown in **Table 13**.

Trajectory plots (**Figure 2**) of projected TACs are shown by recruitment scenario 1 and 2 for each variant of BR and FO using the minimum TAC change threshold. Originally, Panel 2 requested that projected TACs be shown for different assumed index values. SCRS has simplified this to two scenarios that reflect potential index scenarios of relatively constant (e.g. Recruitment level 1) or steeply decreasing (Recruitment scenario 2) biomass (for which resulting indices would then follow) to show how CMPs respond to different future data trends. The trajectory plots illustrate the differences between long-term (e.g. to 2052) and short term (e.g. to 2035) median CMP TAC and biomass performance.

Table 11. Primary quilt plot for all 24 remaining CMP variants. In this table, the CMPs are ordered by the '*Tot*' column.

					West					East					
CMP	PGK	Mgmt cycle	Stability	Min TAC change	PGK (Mean)	AvC10 (50%)	AvC30 (50%)	VarC (50%)	LD (15%)	PGK (Mean)	AvC10 (50%)	AvC30 (50%)	VarC (50%)	LD (15%)	Tot
BR	70	2 yr	-30	No	0.71	2.57	2.2	8.21	0.45	0.7	46.49	38.13	14.63	0.51	0.25
BR	65	2 yr	-30	No	0.65	2.67	2.32	8.38	0.44	0.65	49.3	39.78	15.17	0.48	0.26
BR	65	2 yr	-30	100/1000	0.65	2.69	2.33	9.7	0.44	0.66	49.27	39.72	15.57	0.48	0.29
BR	70	2 yr	-30	100/1000	0.71	2.59	2.2	9.61	0.45	0.71	46.43	38.08	15.18	0.51	0.29
BR	60	2 yr	-30	No	0.6	2.77	2.43	8.81	0.42	0.6	51.97	41.42	15.6	0.45	0.31
BR	60	2 yr	-30	100/1000	0.6	2.77	2.44	10	0.42	0.6	51.97	41.33	15.96	0.45	0.34
FO	60	2 yr	-30	No	0.61	2.89	2.59	14.86	0.4	0.6	46.88	37.19	16.68	0.45	0.55
FO	65	2 yr	-30	100/1000	0.66	2.78	2.5	15.3	0.41	0.65	44.95	35.44	17.02	0.49	0.55
BR	70	3 yr	-30	No	0.7	2.55	2.18	9.75	0.43	0.7	43.27	37.2	17.14	0.44	0.56
FO	65	2 yr	-30	No	0.66	2.79	2.5	14.95	0.4	0.65	45.02	35.42	16.52	0.49	0.56
FO	60	2 yr	-30	100/1000	0.62	2.88	2.59	15.09	0.4	0.6	46.85	37.14	17.08	0.45	0.57
FO	70	2 yr	-30	No	0.71	2.66	2.37	15.03	0.41	0.7	42.71	33.46	16.45	0.52	0.57
BR	65	3 yr	-30	No	0.66	2.63	2.29	10.02	0.42	0.65	45.64	39.19	17.72	0.41	0.58
FO	70	2 yr	-30	100/1000	0.72	2.67	2.37	15.47	0.41	0.7	42.65	33.51	16.71	0.53	0.58
BR	60	3 yr	-35	No	0.6	2.73	2.45	10.45	0.4	0.6	48.37	41.28	18.64	0.41	0.59
BR	70	3 yr	-30	100/1000	0.7	2.57	2.19	10.97	0.43	0.7	43.29	37.28	17.57	0.44	0.59
BR	60	3 yr	-35	100/1000	0.6	2.74	2.46	11.07	0.4	0.6	48.41	41.28	19.23	0.41	0.61
BR	65	3 yr	-30	100/1000	0.66	2.64	2.3	11.02	0.41	0.65	45.65	39.17	17.98	0.41	0.64
FO	60	3 yr	-35	No	0.62	2.59	2.51	17.41	0.42	0.62	47.15	37.75	19.85	0.41	0.74
FO	60	3 yr	-35	100/1000	0.63	2.59	2.51	17.78	0.42	0.62	47.15	37.73	19.98	0.41	0.75
FO	65	3 yr	-30	No	0.66	2.53	2.41	17.11	0.41	0.65	45.71	36.54	19.19	0.42	0.79
FO	70	3 yr	-30	No	0.71	2.43	2.3	17.27	0.42	0.7	43.08	34.46	19.13	0.46	0.79
FO	65	3 yr	-30	100/1000	0.66	2.53	2.41	17.47	0.41	0.65	45.71	36.58	19.26	0.42	0.8
FO	70	3 yr	-30	100/1000	0.71	2.43	2.3	17.8	0.42	0.7	43.12	34.45	19.11	0.46	0.8

Table 12. Secondary quilt plots, shown separately for East (a) and West (b), which depict the following 10 performance statistics - C1: catch (kilotons, kt) in the first year of CMP application; AvC20: average catch (kt) over years 1-20 (50%tile); AvgBr: spawning biomass relative to dynamic SSB_{MSY} over projection years 11-30 (50%), Br20: Depletion (spawning biomass relative to dynamic SSB_{MSY}) in projection year 20 (50%); Br30: Depletion (spawning biomass relative to dynamic SSB_{MSY}) in projection year 30 (5%); $LD^*_{5\%}$: 5%tile of lowest depletion over years 11-30; $LD^*_{10\%}$: 10%tile of lowest depletion over years 11-30; POF: Probability of Overfishing ($U > U_{MSY}$) after 30 projected years (mean); PNRK: Probability of not Red Kobe ($SSB \geqq SSB_{MSY}$ or $U<U_{MSY}$) after 30 projected years (mean), OFT: Overfished trend, SSB trend over projection years 31 - 35 when Br30 < 1. CMPs are ordered by the '*Tot*' column from the primary quilt plot in **Table 11**.

a) East

CMP	PGK	Mgmt cycle	Stability	Min TAC change	C1 (50%)	AvC20 (50%)	AvgBr (50%)	Br20 (50%)	Br30 (5%)	LD (5%)	LD (10%)	POF (Mean)	PNRK (Mean)	OFT (P>0)
BR	70	2 yr	-30	No	40.57	44.29	1.34	1.29	0.58	0.33	0.43	0.06	0.97	0.92
BR	65	2 yr	-30	No	40.57	46.92	1.27	1.22	0.51	0.3	0.41	0.08	0.95	0.9
BR	65	2 yr	-30	100/1000	40.57	46.91	1.27	1.22	0.51	0.3	0.41	0.08	0.95	0.91
BR	70	2 yr	-30	100/1000	40.57	44.26	1.34	1.29	0.58	0.33	0.43	0.06	0.97	0.92
BR	60	2 yr	-30	No	40.57	49.26	1.21	1.15	0.44	0.27	0.38	0.11	0.93	0.88
BR	60	2 yr	-30	100/1000	40.57	49.28	1.21	1.15	0.44	0.27	0.38	0.11	0.93	0.89
FO	60	2 yr	-30	No	38.29	43.88	1.39	1.35	0.3	0.25	0.36	0.25	0.8	0.83
FO	65	2 yr	-30	100/1000	38.29	41.46	1.46	1.42	0.38	0.3	0.42	0.18	0.86	0.86
BR	70	3 yr	-30	No	40.57	42.35	1.38	1.35	0.42	0.25	0.36	0.08	0.93	0.87
FO	65	2 yr	-30	No	38.29	41.54	1.46	1.42	0.37	0.29	0.42	0.19	0.85	0.87
FO	60	2 yr	-30	100/1000	38.29	43.84	1.39	1.35	0.31	0.26	0.36	0.25	0.79	0.83
FO	70	2 yr	-30	No	38.29	38.87	1.52	1.49	0.45	0.34	0.45	0.13	0.9	0.89
BR	65	3 yr	-30	No	40.57	45.08	1.31	1.28	0.34	0.21	0.33	0.12	0.9	0.84
FO	70	2 yr	-30	100/1000	38.29	38.91	1.52	1.49	0.45	0.34	0.45	0.13	0.9	0.89
BR	60	3 yr	-35	No	40.57	48.45	1.25	1.21	0.33	0.21	0.33	0.13	0.89	0.85
BR	70	3 yr	-30	100/1000	40.57	42.21	1.38	1.35	0.41	0.25	0.36	0.08	0.93	0.87
BR	60	3 yr	-35	100/1000	40.57	48.42	1.26	1.21	0.32	0.21	0.33	0.13	0.89	0.85
BR	65	3 yr	-30	100/1000	40.57	45.07	1.31	1.28	0.34	0.21	0.33	0.12	0.9	0.85
FO	60	3 yr	-35	No	38.29	44.51	1.39	1.35	0.25	0.21	0.33	0.22	0.81	0.81
FO	60	3 yr	-35	100/1000	38.29	44.53	1.39	1.35	0.25	0.21	0.33	0.22	0.81	0.81
FO	65	3 yr	-30	No	38.29	42.75	1.42	1.39	0.27	0.21	0.32	0.19	0.83	0.83
FO	70	3 yr	-30	No	38.29	40.19	1.49	1.46	0.35	0.26	0.37	0.13	0.89	0.87
FO	65	3 yr	-30	100/1000	38.29	42.75	1.42	1.39	0.26	0.22	0.33	0.18	0.84	0.83
FO	70	3 yr	-30	100/1000	38.29	40.23	1.49	1.46	0.35	0.26	0.37	0.13	0.89	0.87

b) West

CMP	PGK	Mgmt cycle	Stability	Min TAC change	C1 (50%)	AvC20 (50%)	AvgBr (50%)	Br20 (50%)	Br30 (5%)	LD (5%)	LD (10%)	POF (Mean)	PNRK (Mean)	OFT (P>0)
BR	70	2 yr	-30	No	2.69	2.38	1.5	1.47	0.54	0.2	0.3	0.09	0.94	0.92
BR	65	2 yr	-30	No	2.69	2.52	1.44	1.4	0.51	0.2	0.29	0.13	0.9	0.88
BR	65	2 yr	-30	100/1000	2.73	2.52	1.44	1.39	0.51	0.2	0.29	0.13	0.9	0.88
BR	70	2 yr	-30	100/1000	2.73	2.4	1.49	1.47	0.55	0.2	0.29	0.09	0.94	0.92
BR	60	2 yr	-30	No	2.69	2.64	1.37	1.33	0.46	0.2	0.29	0.18	0.86	0.85
BR	60	2 yr	-30	100/1000	2.73	2.65	1.37	1.33	0.46	0.2	0.28	0.18	0.87	0.85
FO	60	2 yr	-30	No	2.96	2.81	1.37	1.31	0.37	0.16	0.25	0.19	0.86	0.88
FO	65	2 yr	-30	100/1000	2.96	2.69	1.41	1.37	0.42	0.16	0.25	0.11	0.92	0.91
BR	70	3 yr	-30	No	2.69	2.36	1.53	1.51	0.46	0.18	0.28	0.09	0.94	0.92
FO	65	2 yr	-30	No	2.96	2.69	1.41	1.37	0.39	0.16	0.25	0.13	0.9	0.91
FO	60	2 yr	-30	100/1000	2.96	2.81	1.37	1.31	0.4	0.16	0.25	0.17	0.87	0.88
FO	70	2 yr	-30	No	2.96	2.55	1.48	1.45	0.42	0.16	0.25	0.08	0.94	0.93
BR	65	3 yr	-30	No	2.69	2.47	1.48	1.45	0.43	0.18	0.27	0.12	0.91	0.88
FO	70	2 yr	-30	100/1000	2.96	2.54	1.47	1.45	0.44	0.16	0.25	0.07	0.96	0.93
BR	60	3 yr	-35	No	2.69	2.64	1.4	1.37	0.44	0.19	0.27	0.18	0.87	0.84
BR	70	3 yr	-30	100/1000	2.73	2.37	1.53	1.5	0.45	0.17	0.27	0.1	0.94	0.92
BR	60	3 yr	-35	100/1000	2.73	2.64	1.4	1.37	0.43	0.19	0.27	0.17	0.87	0.84
BR	65	3 yr	-30	100/1000	2.73	2.49	1.48	1.44	0.42	0.17	0.27	0.13	0.91	0.88
FO	60	3 yr	-35	No	2.96	2.68	1.4	1.36	0.38	0.18	0.27	0.17	0.87	0.88
FO	60	3 yr	-35	100/1000	2.96	2.69	1.4	1.36	0.39	0.18	0.27	0.17	0.88	0.88
FO	65	3 yr	-30	No	2.96	2.57	1.44	1.41	0.36	0.15	0.25	0.13	0.91	0.9
FO	70	3 yr	-30	No	2.96	2.44	1.5	1.47	0.38	0.15	0.25	0.08	0.94	0.93
FO	65	3 yr	-30	100/1000	2.96	2.57	1.44	1.41	0.36	0.15	0.25	0.12	0.92	0.9
FO	70	3 yr	-30	100/1000	2.96	2.43	1.5	1.47	0.38	0.15	0.25	0.08	0.94	0.93

Table 13. Table of all 24 remaining CMP variants, and their short (C1) and medium (AvC10) yields and variability in yield (VarC).

EAST

CMP	LD	PGK	Cycle	Stability	Min TAC change	C1	AvC10	VarC
BR	15	60	2	+20/-30	No	40,570	51,970	15.6
					100/1000	40,570	51,970	15.98
			3	+20/-35	No	40,570	48,370	18.64
					100/1000	40,570	48,410	19.23
		65	2	+20/-30	No	40,570	49,300	15.17
					100/1000	40,570	49,270	15.57
			3	+20/-30	No	40,570	45,640	17.72
					100/1000	40,570	45,650	17.98
		70	2	+20/-30	No	40,570	46,490	14.63
					100/1000	40,570	46,430	15.18
			3	+20/-30	No	40,570	43,270	17.14
					100/1000	40,570	43,290	17.57

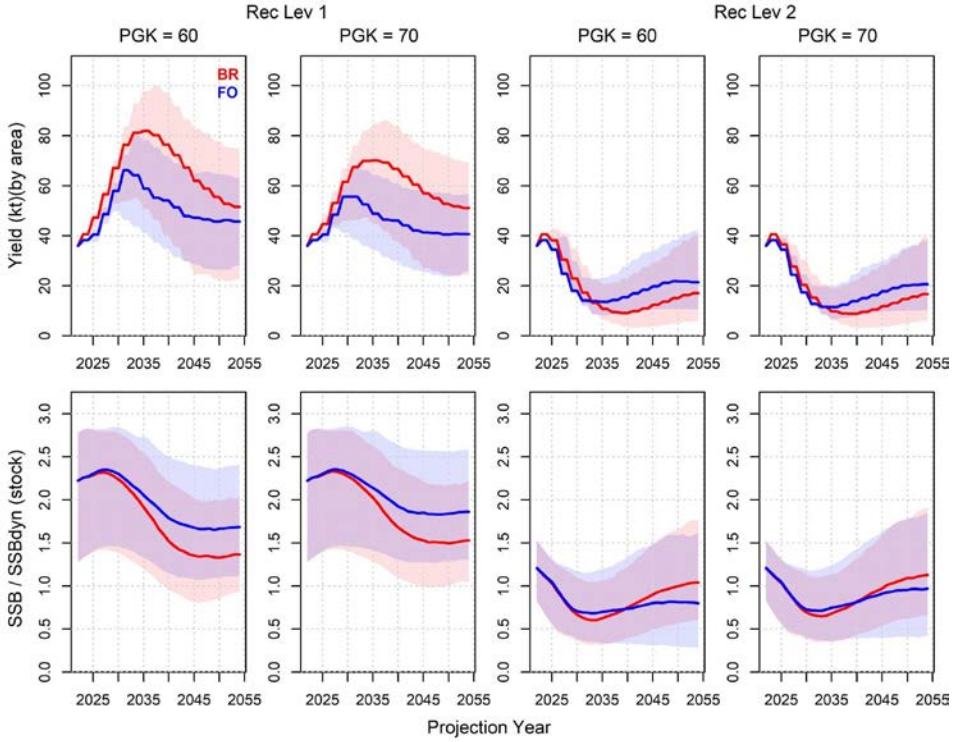
WEST

CMP	LD	PGK	Cycle	Stability	Min TAC change	C1	AvC10	VarC
BR	15	60	2	+20/-30	No	2,690	2,770	8.81
					100/1000	2,726	2,770	10
			3	+20/-35	No	2,690	2,730	10.45
					100/1000	2,726	2,740	11.07
		65	2	+20/-30	No	2,690	2,670	8.38
					100/1000	2,726	2,690	9.7
			3	+20/-30	No	2,690	2,630	10.02
					100/1000	2,726	2,640	11.02
		70	2	+20/-30	No	2,690	2,570	8.21
					100/1000	2,726	2,590	9.61
			3	+20/-30	No	2,690	2,550	9.75
					100/1000	2,726	2,570	10.97

CMP	LD	PGK	Cycle	Stability	Min TAC change	C1	AvC10	VarC
FO	15	60	2	+20/-30	No	38,290	46,880	16.68
					100/1000	38,290	46,850	17.08
			3	+20/-35	No	38,290	47,150	19.85
					100/1000	38,290	47,150	19.98
		65	2	+20/-30	No	38,290	45,020	16.52
					100/1000	38,290	44,950	17.02
			3	+20/-30	No	38,290	45,710	19.19
					100/1000	38,290	45,710	19.26
		70	2	+20/-30	No	38,290	42,710	16.45
					100/1000	38,290	42,650	16.71
			3	+20/-30	No	38,290	43,080	19.13
					100/1000	38,290	43,120	19.11

CMP	LD	PGK	Cycle	Stability	Min TAC change	C1	AvC10	VarC
FO	15	60	2	+20/-30	No	2,960	2,890	14.86
					100/1000	2,960	2,880	15.09
			3	+20/-35	No	2,960	2,590	17.41
					100/1000	2,960	2,590	17.78
		65	2	+20/-30	No	2,960	2,790	14.95
					100/1000	2,960	2,780	15.3
			3	+20/-30	No	2,960	2,530	17.11
					100/1000	2,960	2,530	17.47
		70	2	+20/-30	No	2,960	2,660	15.03
					100/1000	2,960	2,670	15.47
			3	+20/-30	No	2,960	2,430	17.27
					100/1000	2,960	2,430	17.8

a) Yield for the East management area (top panels) and biomass trend for the eastern stock (bottom panels), for 2-year management cycles for the BR (red) and FO (blue) CMPs.



b) Yield for the West management area (top panels) and biomass trend for the western stock (bottom panels), for 2-year management cycles for the BR (red) and FO (blue) CMPs.

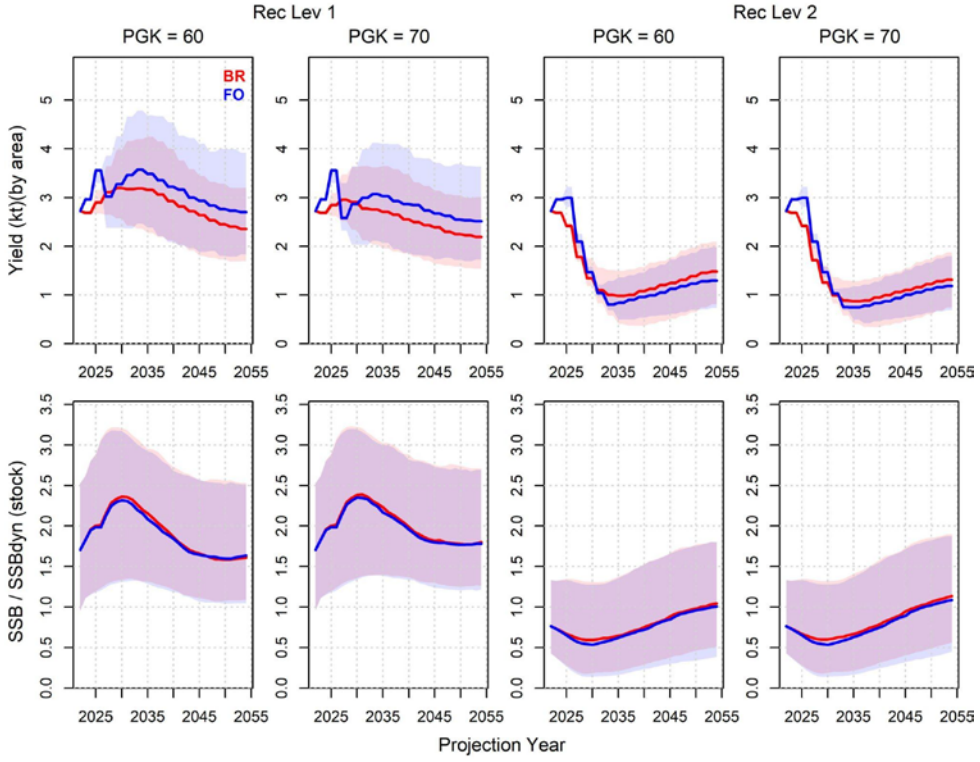
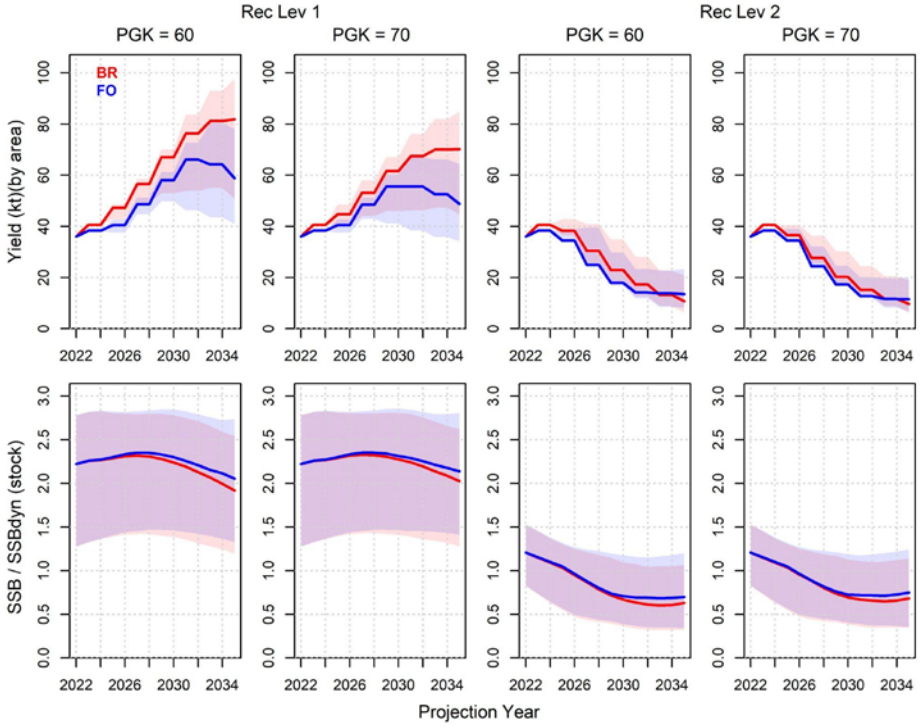


Figure 2. Projected yields and SSB/dynamic SSB_{MSY} for recruitment scenarios 1 and 2. The lines are the medians integrated over-all operating models and simulations of the reference grid for each recruitment scenario. The shaded areas are the 80% inter-quantile range. For each plot, the starting points are the 2022 TACs and SSB-related statistics for both East and West.

c) Truncated version to 2035 of (a). Yield for the East management area (top panels) and biomass trend for the eastern stock (bottom panels), for 2-year management cycles for the BR (red) and FO (blue) CMPs.



d) Truncated version to 2035 of (b). Yield for the West management area (top panels) and biomass trend for the western stock (bottom panels), for 2-year management cycles for the BR (red) and FO (blue) CMPs.

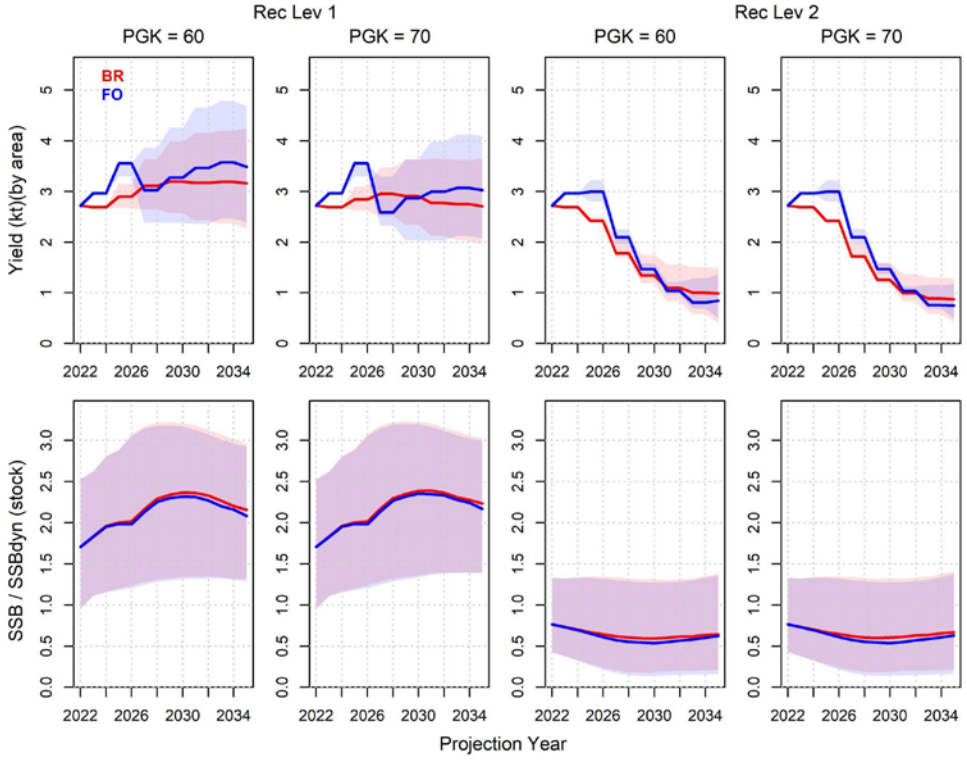
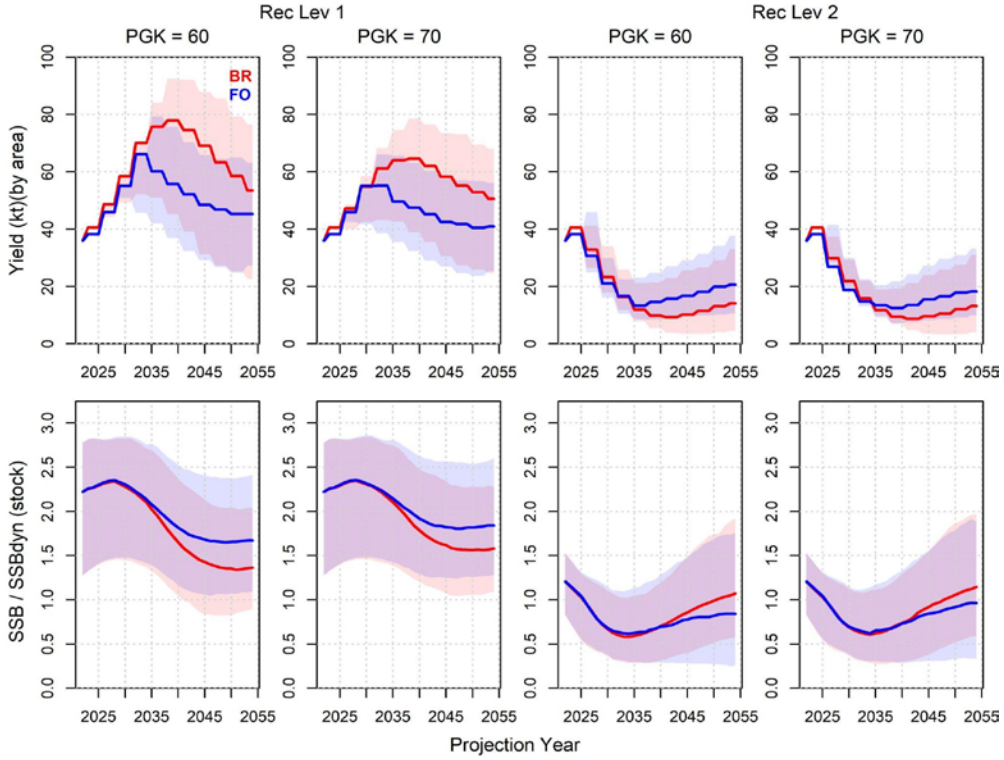


Figure 2. Continued.

e) Yield for the East management area (top panels) and biomass trend for the eastern stock (bottom panels), for 3-year management cycles for the BR (red) and FO (blue) CMPs.



f) Yield for the West management area (top panels) and biomass trend for the western stock (bottom panels), for 3-year management cycles for the BR (red) and FO (blue) CMPs.

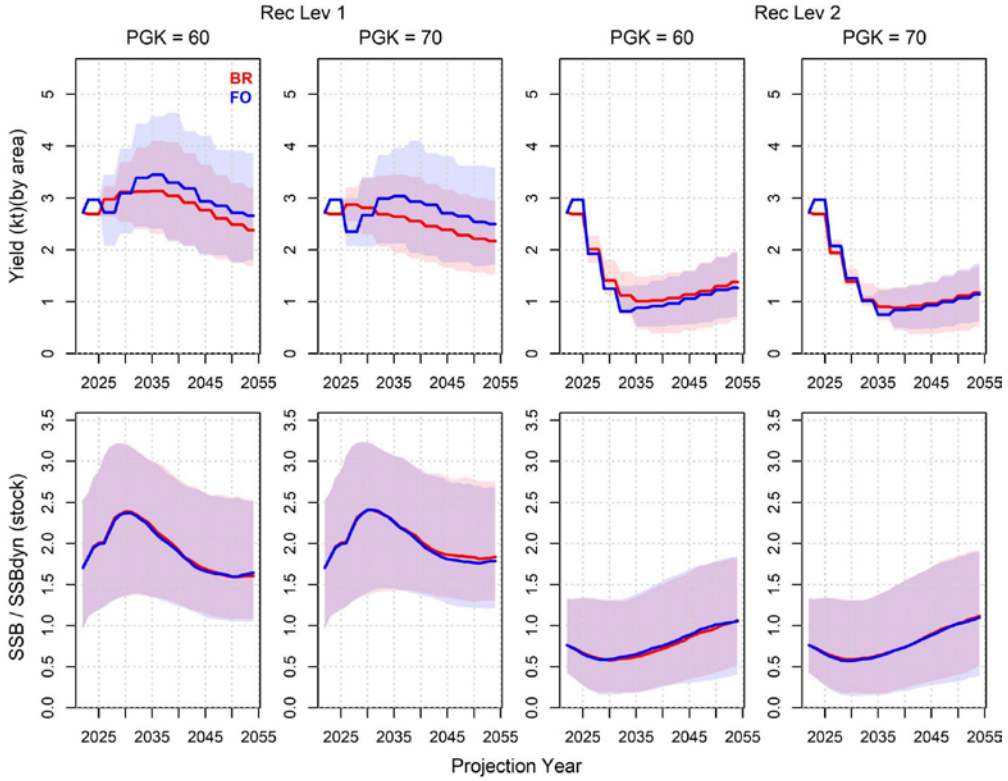
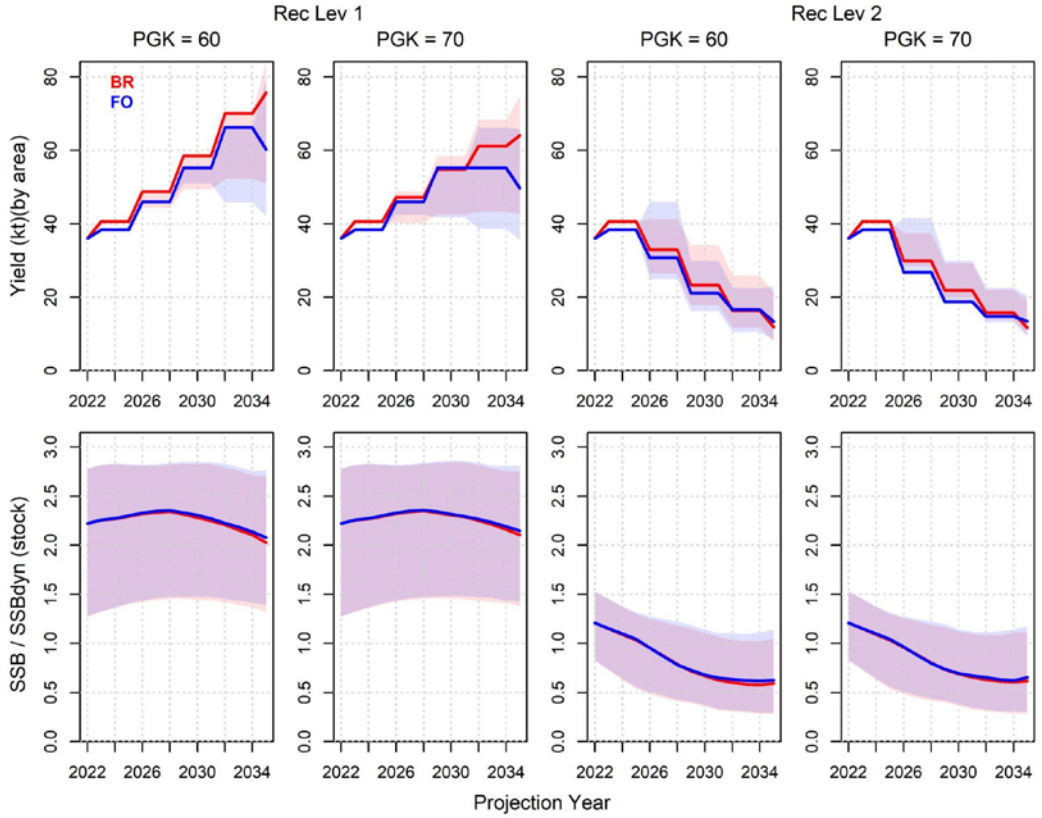


Figure 2. Continued.

g) Truncated version to 2035 of (e). Yield for the East management area (top panels) and biomass trend for the eastern stock (bottom panels), for 3-year management cycles for the BR (red) and FO (blue) CMPs.



h) Truncated version to 2035 of (f). Yield for the West management area (top panels) and biomass trend for the western stock (bottom panels), for 3-year management cycles for the BR (red) and FO (blue) CMPs.

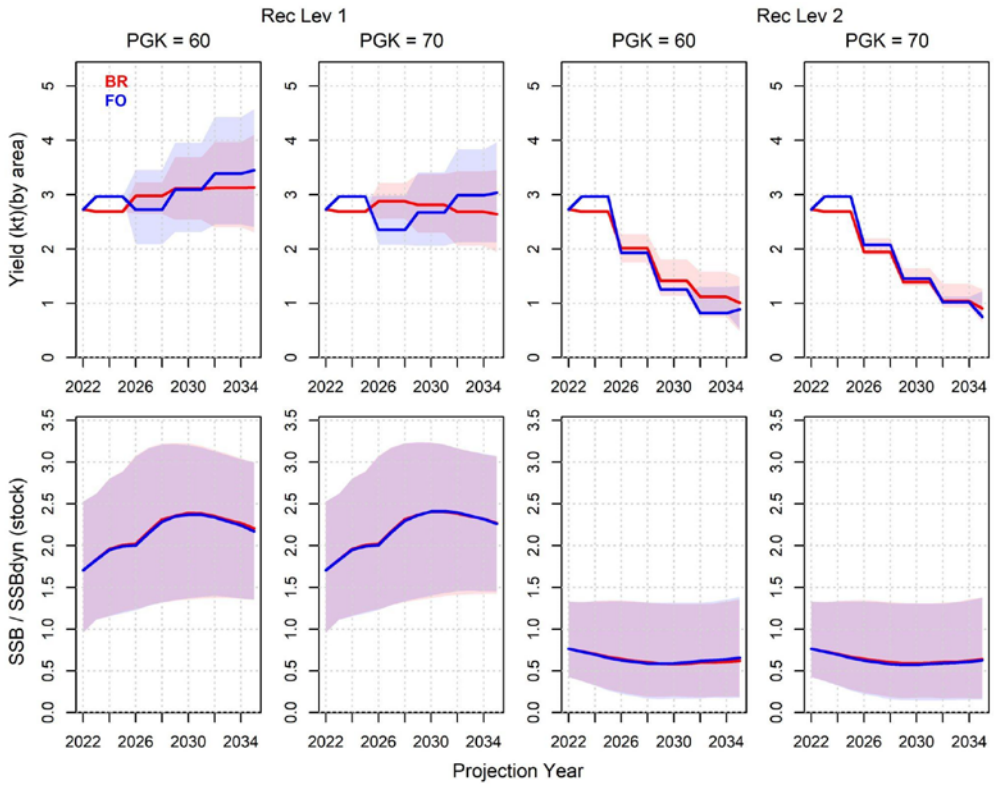


Figure 2. Continued.