Full set of results for the CMP recommended to be adopted for OMP2018, including for the robustness tests conducted thus far

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Summary

This document either summarises previous reported performance statistics and plots, or extends these, to provide a comprehensive consolidation of such results for the OMP candidate to be recommended for the next hake OMP (control parameters *b* increased by 5% and a TAC cap of 160 thousand tons - these being the key changes to OMP-14).

Introduction

This document serves to provide a full set of results for the proposed OMP2018 CMP and for the various robustness tests conducted leading up to the decision to recommend this CMP. The proposed OMP2018 imposes a cap of 160 000t and increases the OMP tuning parameters b_s (the parameters which determine the extent to which TAC responds to changes in survey and CPUE indices) by 5%[2]. Furthermore, OMP2018 fixes the 2019 and 2020 TAC at the 2018 TAC increased by 10% (i.e. an increase from 133 119t to 146 431t).

The first five robustness tests relate to assumptions regarding future surveys:

1. No future surveys
2. All future surveys are conducted by industry vessels
3. Two surveys (WC and SC) take place every second year
4. RC assumptions (i.e. all future surveys continue as normal with the research vessel) but with an undetected increase in CPUE catchability of 2% p.a.
5. No future surveys with an undetected increase in catchability.

More details of these robustness tests can be found in FISHERIES/2018/OCT/SWG-DEM/58. The remaining five robustness tests conducted to date are listed below.

6. The original natural mortality-at-age vectors from the Rademeyer 2017 model for the two hake species are used instead of the ones estimated by the predation model. These mortality-at-age vectors are fixed at 0.75 for lower ages and 0.375 for higher ages.
7. Use of the original algorithm 2013 species splitting results for the CPUE and catch data.
8. Use of the Model A6 species splitting results for the CPUE and catch data.
9. Carrying capacity for both species decreases linearly by 30% between 1980 and 2000. Carrying capacity before 1980 is at the 1917 value, while carrying capacities after 2000 are at 70% of their 1917 values.
10. Carrying capacity for both species decreases linearly by 30% between 2018 and 2022. Carrying capacities after 2022 are at 70% of their 1917 values.

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[2] Note that when the *b* parameters for *M. paradoxus* and for *M. capensis* are modified, this is always such as maintains their original ratio. Sometimes therefore, these b parameters are referenced in the singular rather than the plural.

For robustness tests 9 and 10 that decrease the carrying capacity, a dynamic B_{MSY} has been calculated[3].

Results

The primary performance statistics are listed in Table 1a and b. Figure 1a and b show the median "trajectories", probability envelopes and some worm plots for (female) B/B_{MSY}, catch, effort and CPUE for the proposed OMP2018 (i.e. for an equal weighting across the nine RS OMs).

Graphic illustrations of the performance statistics for the RC and 10 robustness tests are given in Figure 2a and b, while the corresponding plots the median "trajectories" [4] and probability envelopes for B/B_{MSY}, catch, effort and CPUE are shown in Figure 3a and b.

Table 2 lists some further TAC statistics relating to what is to be expected over the next four years, in particular whether the TAC is likely to go up or down after the proposed two years' fixed TAC in 2019 and 2020, and the extent to which the TAC is then likely to change. For a small percentage of the simulations (of the order of 2-3%), not all the TAC is caught in the few instances where this would require a fishing mortality rate which exceeds the upper bound of 0.9 which is imposed. The frequency and magnitude of this occurrence is reported in Table 3.

Finally, Figure 4 splits the results for the RS OMs into the six OMs reflecting a more optimistic view of the *M. capensis* status and the three with a more pessimistic view. This Figure is an update of Figure 6 of FISHERIES/2018/OCT/SWG-DEM/67 for the CMP with a cap of 160 000t and a 5% increase in *b*.

Discussion

Many of the results presented here have not been seen before, as some of the earlier robustness tests were not conducted for the 160 000t cap with b+5% option. However, there is nothing in the results here to contradict earlier conclusions that the proposed OMP2018 performs adequately across the range of robustness tests that have been conducted thus far.

Note that results reported in FISHERIES/2018/OCT/SWG-DEM/68 for the robustness that decrease the carrying capacity did not calculate a dynamic B_{MSY} as has been done here. The depletion performance reported here for *M. paradoxus* using dynamic B_{MSY} is notably more optimistic.

[3] Dynamic *K* is the trajectory that would be followed by a population in the absence of catches in circumstances where population dynamics parameters (in particular those of the stock-recruitment relationship) change over time. This differs from the trajectory for *K* itself as a result of demographically induced delay effects. Dynamic B_{MSY} is conventionally assumed to remain the same proportion of dynamic *K* during such changes. For the performance statistics in the tables though, true and dynamic *K* are the same, as in the years for which the statistics are reported, the transient effects associated with the differences between the two have died out, so that the extra computational complexity of computing dynamic B_{MSY} for all years could be bypassed. The B/B_{MSY} trajectories plotted in Figure 3b for the robustness tests changing *K* are, however, consequently marginally in error.

[4] The reason for placing trajectories in quotes here is that the means and medians here do not reflect actual achieved trajectories in some simulation, but rather joining the mean or median values from the predicted distributions for successive future years. Quotation marks will not be used for this word elsewhere in the document.

Table 1a: The first two rows of the Table list the performance statistics for a CMP similar to OMP2014 (with a cap of 150 000t and no increase in *b*) and the CMP that is being proposed for OMP 2018 (cap of 160 00t and a 5% increase in *b*). The statistics in the first two rows are reported as medians of the equally weighted simulations from the nine RS models (i.e. medians of 9x100 values) with their 90% probability intervals, except for the second columns under TAC_{av}(25 yrs) and TAC_{av} (4yrs) where the means and standard deviations are also listed.

The second part of the table lists the performance statics for the RS02 Reference Case (RC) OM (the RS OM with Ricker stock recruitment and central year of catch shift 1958) and 10 robustness tests, where all tests have been conducted for RS02 only. Where robustness tests involve future occurrences for which it would likely be known beforehand whether they would occur (marked with a star in the table below), the robustness test b_s parameters were tuned so that the risk (defined as the lower 5th percentile of the B_{2042}/B_{MSY} value for *M. paradoxus*) is within half a percent of the RC results. The abbreviation "NS" stands for "no surveys" and "UCI" stands for "undetected catchability increase".

The performance statistics here in Table 1a are B^{sp}/B_{MSY} for 2042 (final year of the projection period) and for 2022 (end of the life span of OMP2018) and B_{low}/B_{MSY} (the lowest value of this statistic in the projection period).

				M. paradoxus						*M. capensis*					
		Cap	b	B_{2042}/B_{MSY}		B_{2022}/B_{MSY}		B_{low}/B_{MSY}		B_{2042}/B_{MSY}		B_{2022}/B_{MSY}		B_{low}/B_{MSY}	
Equal weighting across the nine RS OMs															
	Similar to OMP2014	150	+0%	2.93	(1.55,5.15)	2.12	(1.01,3.46)	1.57	(0.96,2.19)	3.06	(1.07,6.76)	2.95	(0.39,5.18)	2.44	(0.32,4.52)
	Proposed OMP2018	160	+5%	2.67	(1.37,4.81)	2.10	(1.01,3.43)	1.47	(0.90,2.15)	3.01	(0.91,6.70)	2.94	(0.39,5.18)	2.40	(0.32,4.52)
Robustness test results for RS02 only															
0	RC	160	+5%	2.24	(1.21,3.70)	2.24	(1.24,3.61)	1.39	(0.97,1.93)	2.73	(1.69,4.27)	2.83	(2.50,3.41)	2.08	(1.51,2.52)
1	No surveys*		+12.75%	2.38	(1.20,3.96)	2.25	(1.27,3.61)	1.42	(0.97,1.98)	2.79	(1.69,4.50)	2.84	(2.50,3.41)	2.07	(1.45,2.52)
2	All industry*		+1.25%	2.27	(1.21,3.73)	2.24	(1.26,3.61)	1.40	(0.96,1.96)	2.72	(1.71,4.29)	2.83	(2.50,3.41)	2.07	(1.52,2.52)
3	Every second year*	160	+5%	2.28	(1.21,3.75)	2.25	(1.24,3.61)	1.41	(0.97,1.94)	2.75	(1.68,4.21)	2.83	(2.49,3.41)	2.09	(1.54,2.52)
4	RC + UCI		+5%	2.09	(0.99,3.67)	2.24	(1.23,3.61)	1.31	(0.87,1.90)	2.68	(1.60,4.16)	2.83	(2.50,3.41)	2.04	(1.43,2.52)
5	NS+ UCI		+12.75%	2.08	(0.92,3.70)	2.24	(1.27,3.61)	1.30	(0.83,1.90)	2.65	(1.60,4.15)	2.83	(2.50,3.41)	2.01	(1.41,2.52)
6	Original mortality		+5%	2.28	(0.98,4.12)	2.25	(1.24,3.66)	1.31	(0.81,1.76)	2.75	(1.72,4.65)	2.76	(2.25,3.48)	1.78	(1.20,2.34)
7	Alg13 sp. splitting		+5%	2.16	(1.19,3.60)	1.93	(1.06,3.05)	1.37	(0.89,1.74)	3.11	(2.00,4.39)	3.11	(2.70,3.71)	2.58	(1.94,2.80)
8	Model A6 sp. splitting	160	+5%	2.23	(1.26,3.70)	2.35	(1.37,3.70)	1.47	(1.03,1.93)	2.85	(1.75,4.40)	2.92	(2.57,3.47)	2.18	(1.58,2.61)
9	Decrease past K		+5%	3.65	(1.89,6.02)	3.67	(1.88,6.01)	2.14	(1.49,2.94)	2.54	(1.31,4.18)	2.55	(1.30,4.18)	1.49	(1.03,2.04)
10	Decrease Future K		+5%	2.77	(1.45,4.57)	2.85	(1.58,4.80)	1.48	(1.07,2.06)	1.78	(0.93,2.94)	1.83	(1.02,3.09)	0.95	(0.69,1.32)

Table 1b: Continuation of the performance statistics from Table 1a, listing the catch related performance statistics. The statistics reported here are C_{av} (the average catch over the projection period and over the next four years) both in median and mean terms, and AAV (the average inter-annual proportional change in catch over the projection period and over the next four years), in median terms.

		Species combined											
		Cav (25 yrs)				Cav (4 yrs)							
		Median	(90% P.I)	Mean	(sd)	Median	(90% P.I)	Mean	(sd)	AAV (25 years)		AAV (4 years)	
Equal weighting across the nine RS OMs													
	OMP2014	146.55	(135.43,149.70)	145.09	(4.89)	145.55	(140.21,148.22)	144.59	(3.66)	0.020	(0.005,0.043)	0.043	(0.031,0.056)
	Proposed OMP2018	154.08	(140.59,158.87)	152.33	(6.16)	148.13	(140.97,153.22)	147.50	(5.48)	0.025	(0.008,0.048)	0.048	(0.038,0.063)
Robustness test results for RS02 only													
0	RC	152.33	(144.23,157.93)	151.65	4.85	153.22	(141.21,153.22)	150.22	4.30	0.029	(0.013,0.044)	0.048	(0.039,0.060)
1	No surveys*	150.32	(140.27,156.26)	149.11	5.55	150.19	(141.47,153.48)	148.54	4.85	0.035	(0.019,0.047)	0.048	(0.038,0.055)
2	All industry*	152.25	(142.32,158.18)	151.17	5.06	153.04	(141.47,153.48)	150.00	4.53	0.031	(0.016,0.045)	0.048	(0.040,0.062)
3	Every 2nd year*	152.34	(143.35,157.50)	151.31	5.38	153.08	(141.47,153.48)	150.50	4.15	0.033	(0.017,0.045)	0.048	(0.040,0.060)
4	RC + UCI	157.35	(149.92,159.13)	156.02	3.60	153.48	(141.47,153.48)	151.05	3.92	0.019	(0.008,0.034)	0.048	(0.036,0.055)
5	NS+ UCI	157.57	(151.55,159.13)	156.37	3.57	152.33	(141.47,153.48)	149.98	4.41	0.016	(0.008,0.032)	0.048	(0.038,0.055)
6	Original mortality	152.89	(145.86,158.94)	152.48	5.04	153.48	(141.47,153.48)	151.05	3.92	0.027	(0.009,0.042)	0.048	(0.037,0.056)
7	Alg13 sp. Splitting	156.01	(147.85,159.13)	154.61	4.58	153.48	(141.47,153.48)	150.69	4.17	0.020	(0.008,0.039)	0.048	(0.039,0.058)
8	Model A6 sp. Splitting	151.57	(143.81,157.75)	151.11	4.71	153.48	(141.47,153.48)	150.88	4.06	0.032	(0.017,0.045)	0.048	(0.038,0.056)
9	Decrease past K	150.55	(142.51,157.38)	150.10	5.00	152.92	(141.47,153.48)	149.91	4.61	0.034	(0.019,0.046)	0.048	(0.040,0.060)
10	Decrease Future K	139.21	(128.56,151.24)	139.79	7.43	151.61	(141.47,153.48)	149.39	4.80	0.052	(0.035,0.076)	0.048	(0.039,0.060)

Table 2: Some additional statistics for the TACs for the next four years. This Table has been reproduced from Table 4 in FISHERIES/2018/OCT/SWG-DEM/67, which reported results for seven different CMPs. The results from the other CMPs have been retained here for comparison purposes. In the Table, "uu" means $TAC_{2021} \geq TAC_{2020}$ and $TAC_{2022} \geq TAC_{2021}$, "dd" means $TAC_{2021} < TAC_{2020}$ and $TAC_{2022} < TAC_{2021}$, "ud" means $TAC_{2021} \geq TAC_{2020}$ and $TAC_{2022} < TAC_{2021}$ and "du" means $TAC_{2021} < TAC_{2020}$ and $TAC_{2022} \geq TAC_{2021}$. Note that the range of change in TAC (in thousand tons) might be a little counter-intuitive. For example, for a cap of 150 000t, if TAC_{2020}=146 431t, then the maximum increase one would expect in 2021 would be 150 000-146 431=3569 and yet the maximum of the range is 10 270t. This is because there is a rule built into the projection code that the total fleet-summed fishing mortality rate cannot exceed 0.90, and if it does then the catch is reduced. Thus TAC_{2020} could at times be less than 146 431. Table 3 below reports some statistics regarding instances of the TAC not being caught.

		Proportion of 900 simulations				TAC2021-TAC2020		TAC2022-TAC2021	
cap	*b*	uu	dd	ud	du	Mean ('000 t)	Range ('000 t)	Mean ('000 t)	Range ('000 t)
150	+0%	0.38	0.40	0.04	0.17	-2.49	(-18.32,10.27)	-1.62	(-27.83,13.65)
	+5%	0.46	0.31	0.06	0.17	-1.35	(-18.32,10.56)	-1.22	(-27.83,12.62)
	+10%	0.55	0.23	0.08	0.14	-0.30	(-18.32,13.85)	-0.91	(-27.83,12.62)
160	+0%	0.35	0.40	0.07	0.17	0.65	(-18.32,14.26)	-0.80	(-27.83,14.79)
	+5%	0.43	0.31	0.09	0.17	2.70	(-18.32,14.26)	-0.37	(-27.83,14.80)
	+10%	0.52	0.23	0.11	0.14	4.68	(-18.32,14.26)	-0.16	(-27.83,14.79)
no cap	+5%	0.43	0.31	0.09	0.17	3.15	(-18.32,14.93)	4.77	(-27.83,16.42)

Table 3: Reproduction of Table 5 of FISHERIES/2018/OCT/SWG-DEM/67, showing a summary of the TAC projected not to be caught over the next four years (TAC is not caught in a given simulation when the total fleet-summed fishing mortality rate exceeds 0.90). For each year, the percentage of the 9x100 simulations for which the TAC is not caught fully is listed, as well as the average value of the catch not caught (in thousand tons) and the range of the catch not caught. For 2018 to 2020 the statistics are the same for the seven CMPs, as the CMP rules effectively come into play only from 2021 only.

Year	cap	*b*	Percentage of 9x100 simulations for which not all TAC is caught	Average TAC not caught ('000 t)	Range TAC not caught ('000 t)
2018	NA		1.78	5.76	(4.61, 7.07)
2019			2.11	7.33	(4.61, 9.22)
2020			2.33	7.53	(3.65, 10.56)
2021	150	+0%	2.33	6.67	(3.84, 11.30)
		+5%	2.44	7.29	(3.84, 17.19)
		+10%	2.67	7.46	(3.84, 18.16)
	160	+0%	2.33	6.69	(4.21, 11.30)
		+5%	2.44	7.32	(4.21, 17.19)
		+10%	2.67	7.64	(4.21, 20.28)
	no cap	+5%	2.44	7.32	(4.21, 17.19)
2022	150	+0%	2.33	5.52	(3.26, 7.76)
		+5%	2.56	5.68	(3.39, 8.04)
		+10%	2.89	6.08	(3.70, 9.85)
	160	+0%	2.33	5.59	(3.26, 7.76)
		+5%	2.56	5.79	(3.39, 8.04)
		+10%	3.11	6.27	(3.70, 9.85)
	no cap	+5%	2.56	5.89	(3.39, 9.22)

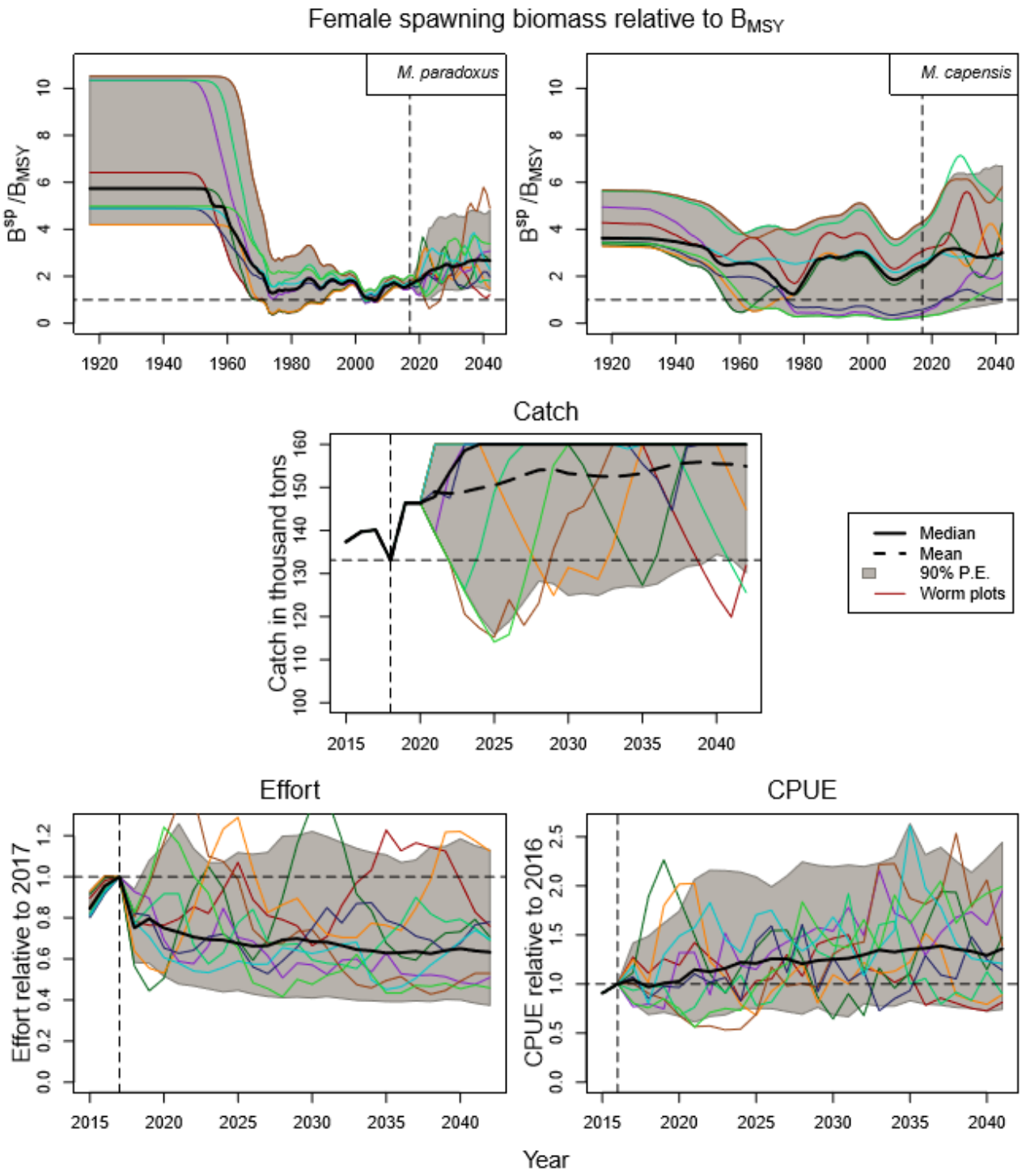

Figure 1a: Trajectories are shown for the proposed OMP2018, with a cap of 160 000t and a *b* increased by 5% from the OMP2014 values, for an equal weighting across the nine RS OMs. Results are shown for female spawning biomass relative to B_{MSY}, catch, effort (taken to be proportional to the estimated *M.* paradoxus WC offshore fishing mortality rate, and normalised to be one in the last year of the OM, i.e. 2017) and CPUE (normalised to be one in the last year for which data are available for the OM, i.e. 2016). In each case the median trajectories are shown by the black solid lines, the 90% probability envelopes are shown by the grey shaded area, and a selection of worm plots are shown by the coloured lines, consisting of one random simulation drawn from the set of 100 simulations for each RS OM. The mean catch trajectory has also been included.

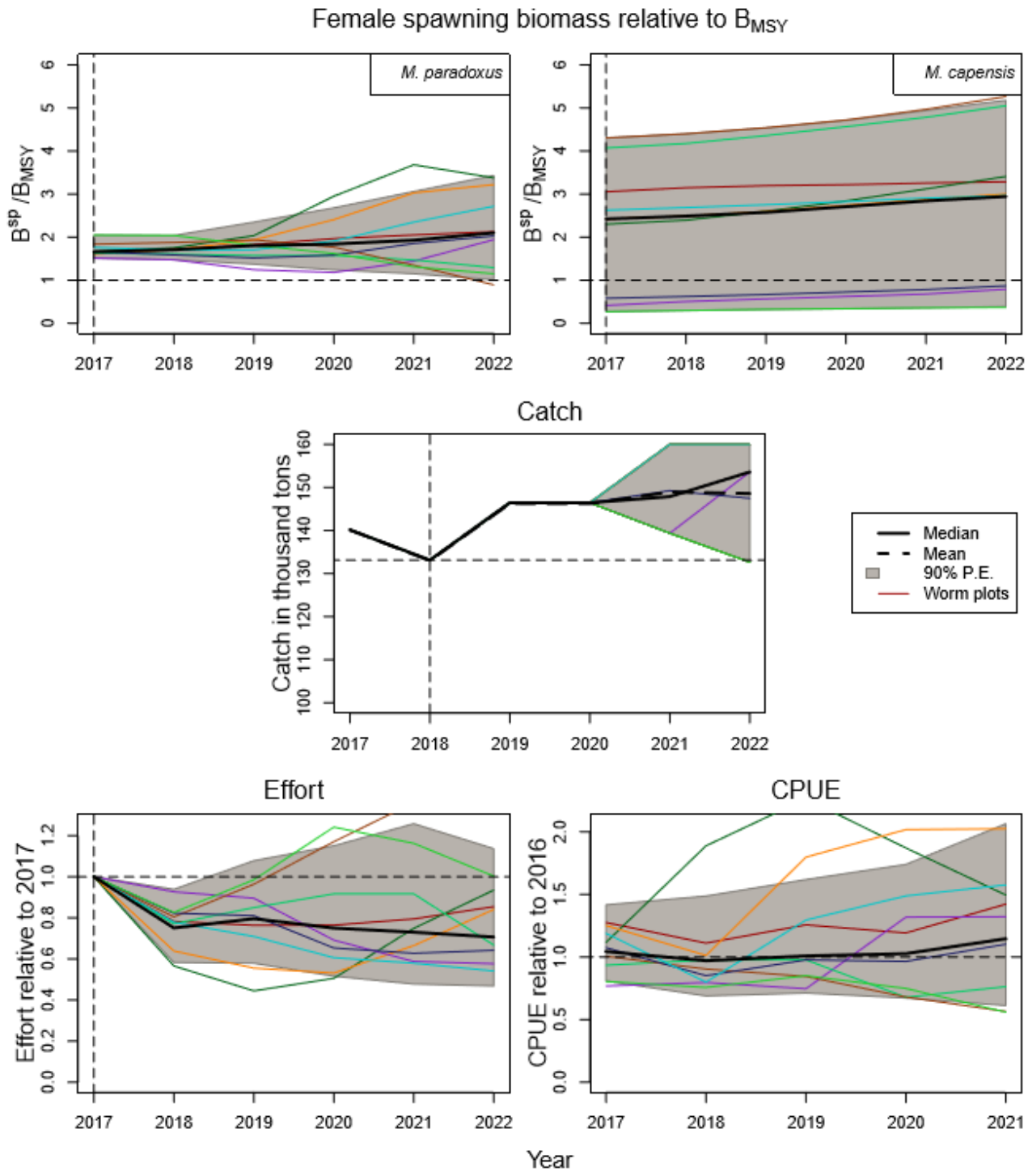

Figure 1b: Repeat of Figure 1a, but with the year-axis restricted to the lifespan of OMP2018.

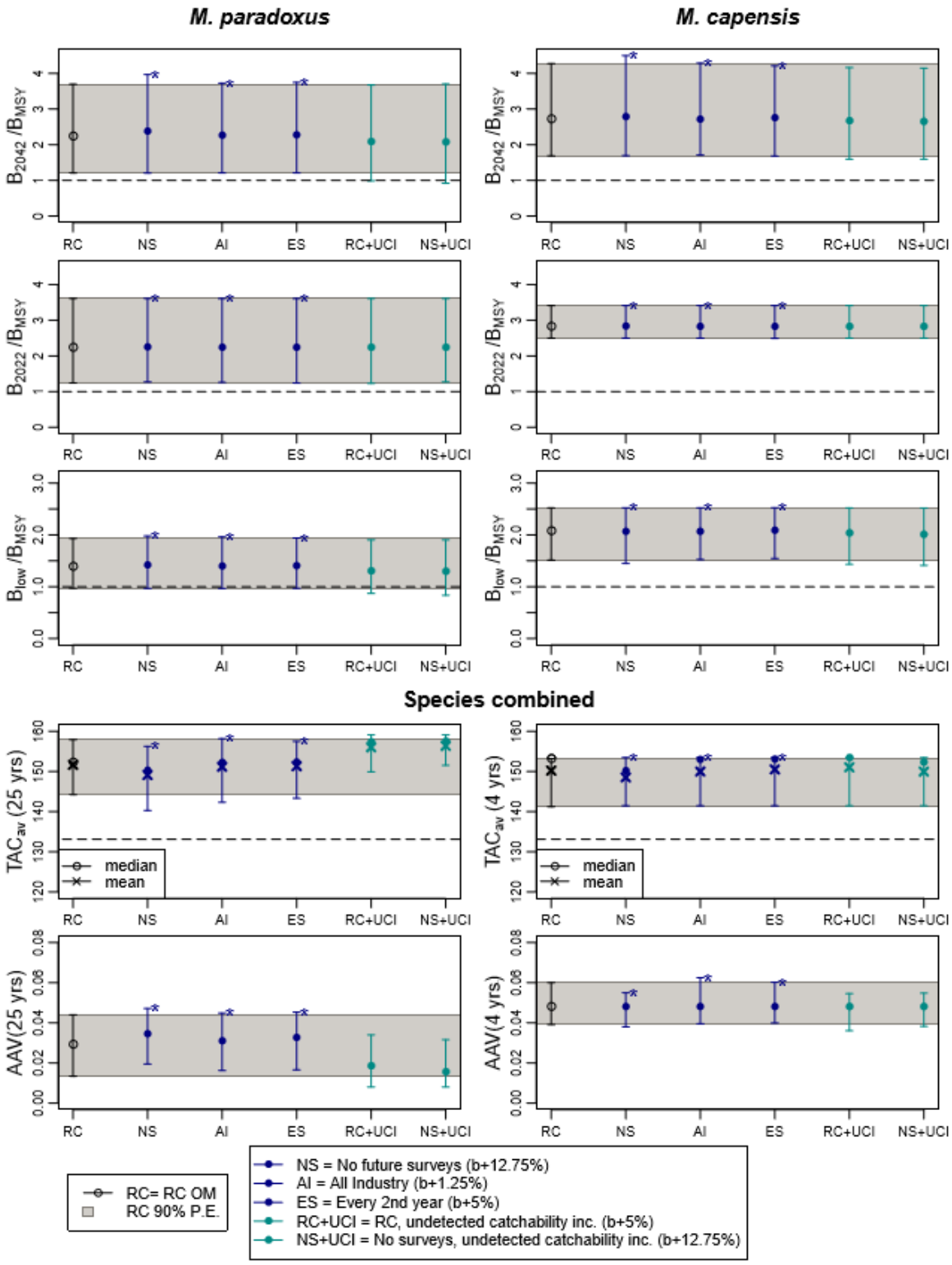

Figure 2a: Zeh plots of the performance statistics from Table 1**, for the RC and first five robustness tests**. These results are thus for the RS02 RC only and not an equal weighting across the RS. The statistics are B^{sp}/B_{MSY} for 2042 and 2022, $B^{sp}(low)/B_{MSY}$ (the lowest value of this statistic in the projection period to 2042), TAC_{av} (the average catch over the projection period (25 years) and over the next four years) and AAV (the average inter-annual proportional change in catch over the projection period (25 years) and over the next four years). Medians and 90% probability intervals are shown. For TAC_{av}, the means are also shown by crosses. For each plot the 90% probability envelope for the RC is indicated by the grey shaded area for comparison purposes. Robustness tests that have been retuned to match the RC risk level for *M. paradoxus* are marked by an asterisk.

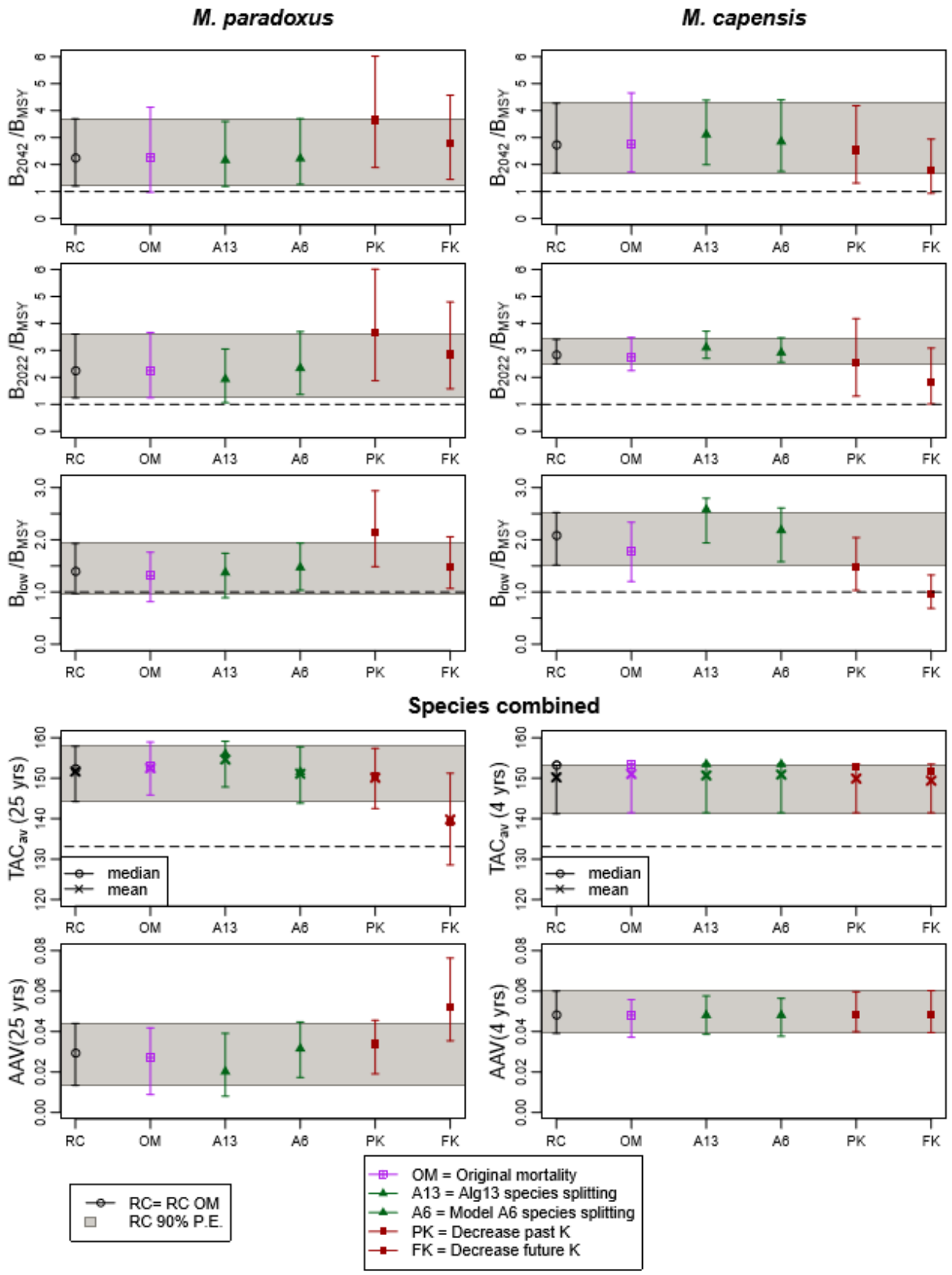

Figure 2b: Zeh plots of the performance statistics from Table 1**, for the RC and second set of five robustness tests**.

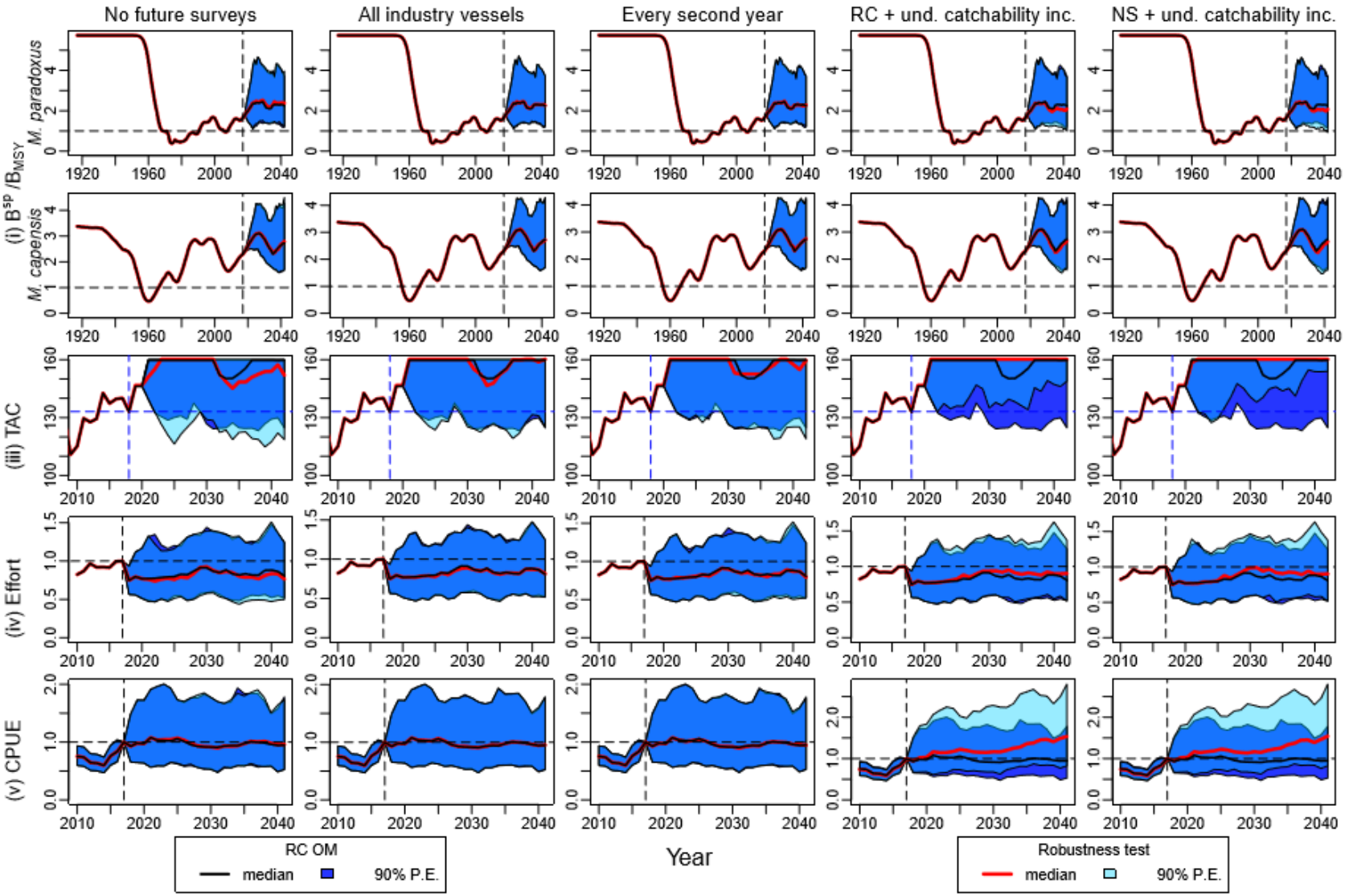

Figure 3a: Projected trajectories for B^{SP}/B_{MSY}, TAC, effort and CPUE are shown for the **RC and first five robustness tests**. The RS02 RC OM results are shown by the black lines (median trajectories) and dark blue shading (90% P.E.), while the robustness test results are indicated by the red lines and light blue shading. Areas of overlaps between the two P.E.'s are indicated by an intermediate blue.

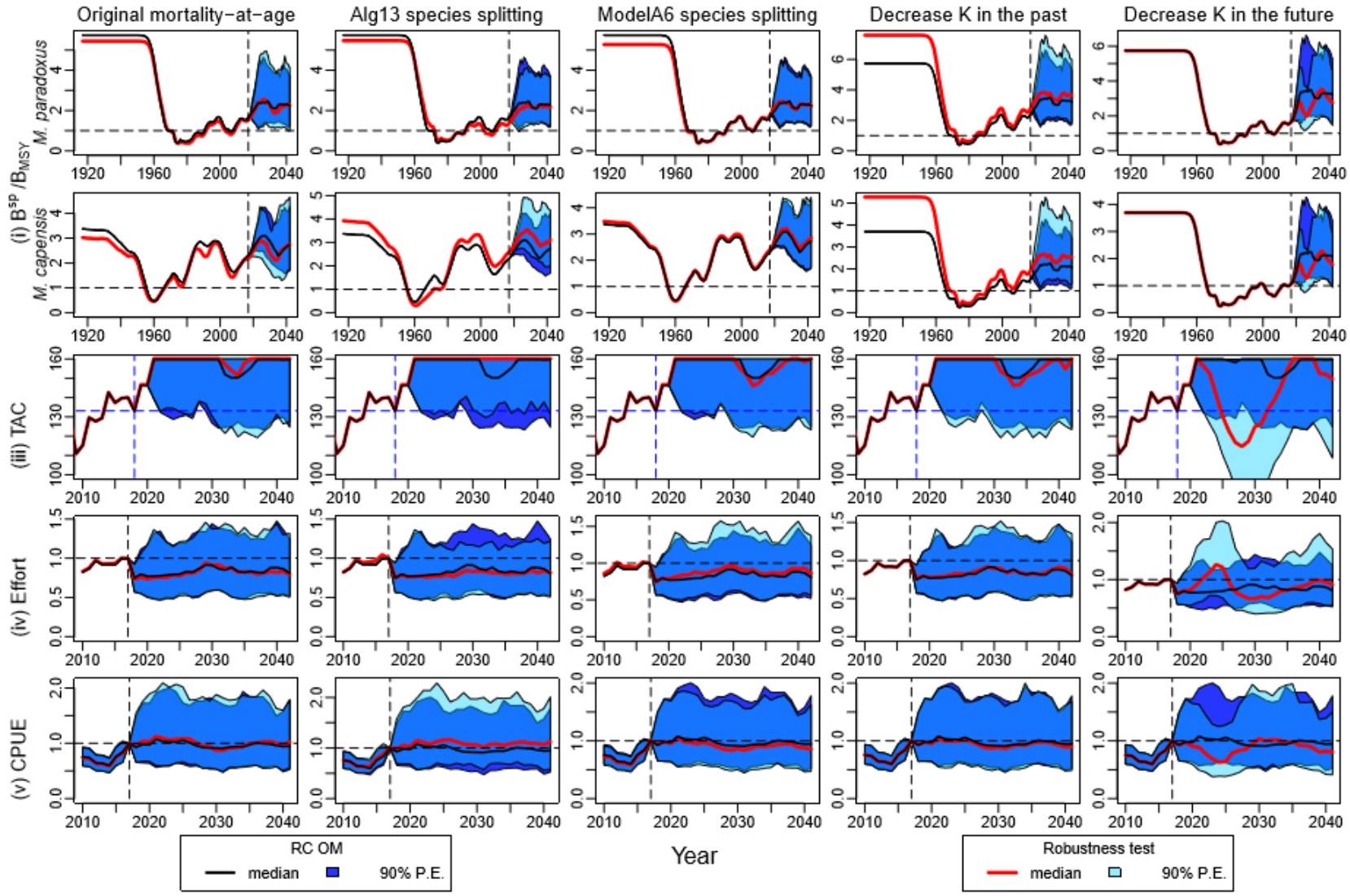

Figure 3b: Projected trajectories are shown for the **RC and second set of five robustness tests**.

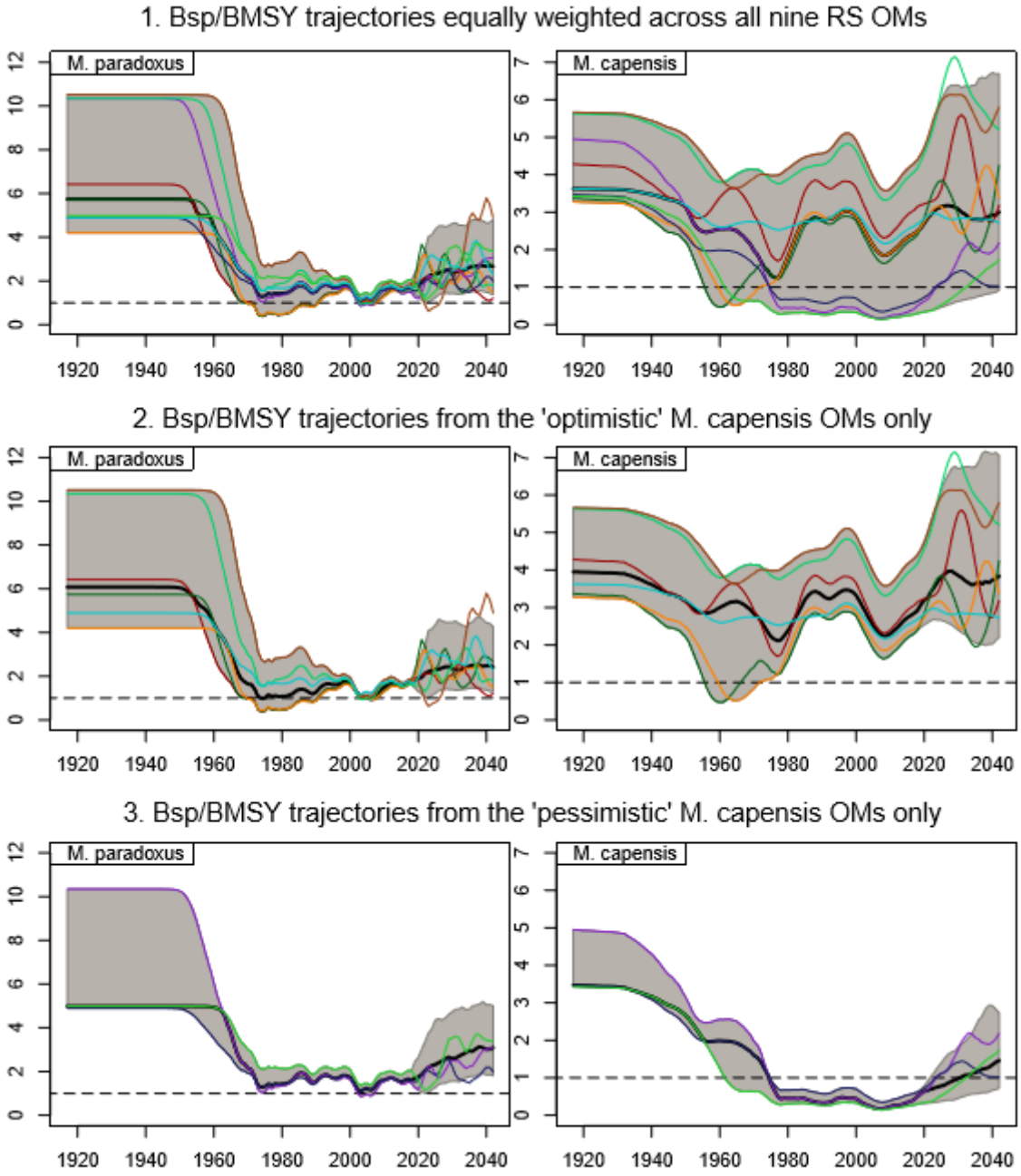

Figure 4: Trajectories for B^{sp}/B_{MSY} are shown for an equal weighting across (a) all nine RS models, (b) only the "optimistic" *M. capensis* RS OMs where the B_{2017}/B_{MSY} estimate is greater than one (six OMs in total) and (c) only the "pessimistic" OMs where the *M. capensis* B_{2017}/B_{MSY} estimate is less than one (three OMs in total). All statistics are reported as medians with 90% probability intervals. The black lines and grey shaded areas show the median "trajectories" and 90% P.E's. The worm plots show a selection of simulations with one simulation drawn at random from each OM. The results shown here are for the proposed OMP2018 with a cap of 160 000t and *b* increased by 5%.