And yet Further Candidate Management Procedure Testing for the South African Hake Resource

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Abstract

This document reports progress on hake OMP revision issues identified at the last DWG meeting as requiring further attention. In particular it updates the Reference Case CMP in terms of the agreements reached at that meeting. Suggestions are made for the final set of calculations needed before a selection is made amongst CMPs at the following DWG meeting. In addition, proposals are made concerning revision of the hake-specific sections of the document governing "exceptional circumstances" for overriding an OMP TAC recommendation or bringing forward an OMP review. These include provisions relating the MSC condition concerning specification of Target and Limit Reference Points for *M.paradoxus*.

Introduction

The specific hake OMP revision issues listed for further attention in the Aide Memoire for the last DWG meeting held on 13 August, 2010 that are addressed here are:

- Extension to an updated Reference Case CMP (**CMPf1a**) in terms of the selections made at that DWG meeting.
- Impacts of alternative intensities for surveys.
- Implications of impacts on CPUE through the introduction of MPAs.
- Further robustness tests, including one specified by OLRAC.
- Use of a five year average in the CMP formula, with increased λ.
- Updating of the "Procedures for deviating from OMP output" document for hake, including specification of an abundance Limit Reference Point with action to be taken if annual routine assessment updates indicate that it is being approached, and inclusion of a survey/CPUE discrepancy statistic.

The last meeting decided that Impacts of rollover/under arrangements would not be sufficiently large to warrant attention in this OMP revision process.

Suggestions for further work needed to finalise the current hake OMP revision process are put forward.

Results and Discussion

For ease of reference, the full set of CMPs considered in this document are listed in Table 1a, with their control parameter values given in Table 1b.

Updated Reference Case: CMPf1a

As agreed at the last DWG meeting, the Reference Case CMP has been updated to incorporate the following features:

- Inclusion of a phase-in of a target term;
- Inter-annual TAC changes restricted to -5%, +10%, with no cap on the TAC;
- Inclusion of a penalty term, as in CMPe2a (equations 1 and 2, Rademeyer and Butterworth, 2010), to secure improved performance for certain more severe robustness tests;
- Reduction of the median average TAC (2011-2020) tuning range to 127-137 000t;
- Incorporation survey as well as CPUE inputs into the target term.

The manner in which this last feature has been incorporated is elaborated below (note that symbols already used in earlier papers have not been redefined here):

$$C_y^{spp} = w_y C_{y-1}^{*spp}\left[1+\lambda_{up/down}\left(s_y^{spp} - T^{spp}\right)\right] + \left(1-w_y\right)\left[a^{spp} + b^{spp}\left(J_y^{spp}-1\right) - c^{spp}\left(J_y^{spp} - p^{spp}\right)^2\right] \quad (1)$$

where

$$J_y^{para} = \frac{1.0J_y^{WC\_CPUE,para} + 0.75J_y^{SC\_CPUE,para} + 0.5J_y^{WC\_surv,para} + 0.25J_y^{SC\_surv,para}}{2.5} \quad (2)$$

$$J_y^{cap} = \frac{1.0J_y^{WC\_CPUE,cap} + 0.75J_y^{SC\_CPUE,cap} + 0.5J_y^{WC\_surv,cap} + 1.0J_y^{SC\_surv,cap}}{3.25} \quad (3)$$

with

$$J_y^{CPUE,i,spp} = \frac{\sum_{y'=y-4}^{y-2} I_y^{CPUE,i,spp}}{\theta^{spp}\sum_{y=2006}^{2008} I_y^{CPUE,i,spp}} \quad \text{and} \quad J_y^{surv,j,spp} = \frac{\sum_{y'=y-3}^{y-1} I_y^{surv,j,spp}}{\theta^{spp}\sum_{y=2007}^{2009} I_y^{surv,j,spp}}$$

with

θ^{para}= 1.67 and θ^{cap} = 1.50, and

w, a^{spp}, b^{spp} , c^{spp} and p^{spp} are tuning parameters,

and where the final term in equation (1) comes into play only if $J_y^{spp} < p^{spp}$

$$MaxDecr_y = \begin{cases} x\% & \text{if } J_y > Q_{\min} \\ \text{linear between } x\% \text{ and } 25\% & \text{if } Q_{\min} - 0.2 \leq J_y \leq Q_{\min} \\ 25\% & \text{if } J_y < Q_{\min} - 0.2 \end{cases} \qquad (4)$$

where

$$J_y = \frac{J_y^{para} + J_y^{cap}}{2}$$

Results for variants of this updated Reference Case are reported in Table 2 for tunings to a median average TAC over the next decade of 127, 132 and 137 thousand tons, the last being the new Reference Case CMPf1a. Note from Table 2b that these three variants show the median spawning biomass reaching B_{MSY} by 2016 or 2017.

Fig 1a plots a large number of projection statistics for CMPf1a, with some worm plots being added in Fig, 1b. Fig. 1c compares median and lower 2.5%iles for the TAC and for B^{sp}/B^{sp}_{2010} for *M. paradoxus* under RSa.

The more severe robustness tests

In Rademeyer and Butterworth (2010), the quadratic penalty term in equation (1) above was found to be needed to secure improved performance in relation to *M. paradoxus* depletion risk for some of the more severe robustness tests. Table 3 and Fig. 2 show results for these tests under the updated Reference Case CMPf1a. Note that with the introduction of the survey data into the penalty term of equation (1), there is better performance in terms of the lower 2.5%ile for *M. paradoxus* under an undetected trend in CPUE catchability (Rob35) than when there are no future surveys (Rob31f).

Table 2 shows that a negative aspect of the change of Reference Cases from CMPc1a to CMPf1a is that the "lowest TAC" statistic drops by almost 10 thousand tons. The variants of CMPf1a for which results are reported in Table 5 seek an improved compromise. Dropping the penalty term of equation (1) altogether (CMPf3a) improves the lowest TAC under RS1 by nearly 10 thousand tons, but *M. paradoxus* can then be rendered virtually extinct under Rob13 (a decrease in *K* in the past). For CMPf4a, reducing the values of p^{spp} compared to CMPf1a gains little in terms either of increasing "low para" under Rob13 compared to the no penalty situation for CMPf3a, but also gains little under RS1 in terms of increasing "lowest TAC" compared to CMPf1a. On balance our suggestion is to **retain CMPf1a** as the Reference Case

Impacts of alternative intensities for surveys.

Table 5 shows results under CMPf1a for a series of scenarios where either or both of future surveys yield weaker information or future CPUE data are biased. Typically both TACs and risk increase. If the CMP is retuned for equivalent risk for the Rob 31g situation (surveys only every second year), the average TAC drops by about 5 thousand tons and the reduction in information input is also reflected by a wider distribution of potential TAC values (compare "lowest TAC" values in Table 5).

Implications of impacts on CPUE through the introduction of MPAs

Table 6 shows the implications of applying CMPf1a if the comparability of CPUE data is compromised in various ways (whose magnitude or direction would not be known in practice) through the (immediate) introduction of MPAs. The specific possibilities examined are:

- Rob33a: no future CPUE data accepted for OMP input.
- Rob33b: new CPUE with prior on q: For each 20-year simulation, the change in ln*q* is drawn from $N(0;0.1^2)$:

  $$\ln q^{new} = \ln q^{old} + \varepsilon^q$$

  where ε^q from $N(0{,}0.1^2)$
- Rob33c: new CPUE with lower *q*:

  $$\ln q^{new} = \ln q^{old} - 0.2$$
- Rob33d: new CPUE with higher *q*.

  $$\ln q^{new} = \ln q^{old} + 0.2$$

Note that the fact that *q* has changed is not known, and hence not known either to the MP in place.

Generally the average TAC increases, but so does the risk, for these scenarios, except in the case of Rob33c for which the reverse effect occurs. If the CMPf applied to Rob33d is retuned to the same risk level as for RSa under CMPf1a, the median average TAC over the next decade drops by about 10%.

OLRAC robustness test

In response to a request, OLRAC provided results for their coding of Reference Set scenario (specifically RS11) to provide the basis for a robustness test. An error was found in the results first provided, so that OLRAC refitted this scenario after correcting this error. Comparative results for the coding used for the RS and parameters estimated using OLRAC's coding (RobOLRAC) are shown in Table 7. It should be noted that when the parameters provided by OLRAC are used in the existing RS assessment code to project from the inception of the fishery to the current year, the results provided by OLRAC for current numbers-at-age are not reproduced.

The Table 7 and Fig 2d results show that if RobOLRAC reflects the actual situation, implementation of CMPf1a will lead to appreciably higher TACs than for the comparable RS11 trial, as appropriate for a situation where (RobOLRAC) the *M. paradoxus* population is computed (in terms of the dynamics of the standard projection code) to be above B^{sp}_{MSY} at present rather than well below as in the case of RS11.

Using a five-year average of the catch in the CMP formula, with increased λ

At the last DWG meeting, variant CMPc1aJ* (which bases TACs on the average TAC over the last five years rather than the previous year's TAC only) was argued to show inferior performance to the then Reference Case CMPc1a. This was because of a lower average TAC over the next decade and oscillatory behaviour of the TAC (in median terms) over the next few years. A further variant has since been examined, as requested at the last DWG meeting, which involves increasing the λ parameters of the control rule before retuning to the same risk as achieved by CMPc1a.

The results are shown in Table 8 and Fig. 3. These indicate that increasing the λ values does increase the average TAC somewhat (though still not to the same level as under CMPc1a). However this gain is achieved at the expense of greater amplitude in the short term TAC oscillations, a substantially lower "lowest TAC", and a near doubling of the average inter-annual TAC variation statistic AAV. Performance thus appears to remain inferior to the previous Reference Case (CMPc1a), and there seems no reason to suspect that the result under CMPf1a would be any different.

Amendments to "Procedures for Deviating from the hake OMP output for the recommendation for a TAC, and for initiating an OMP review"

A part of the hake OMP revision process is consideration for possible amendment of the hake-specific entries in this "exceptional circumstances" document. Such entries are made in two contexts, with present wording along the following lines:

1) Examples of what might constitute exceptional circumstances, with the following non-exhaustive set listed:

- Survey estimates of abundance that are appreciably outside the bounds predicted in OMP testing
- CPUE trends that are appreciably outside the bounds predicted in OMP testing
- Catch species composition in major components of the fishery or surveys that differ markedly from previous patterns (and so may reflect appreciable changes in selectivity).

2) Issues to be considered annually in checks of whether the OMP is running "on track" – note that the Reference Case assessment (here RS1) is updated every year in this process, and every second year this includes updates for the full Reference Set and some major robustness tests:

- Whether over recent years the species splits of catches from the major fisheries differ substantially from the species splits considered in projections in the OMP testing
- Whether selectivities-by-age for the major fisheries differ substantially from assumptions made to generate operating model projections
- Whether CPUE and survey abundance estimates are within the bounds projected by the operating model projections
- Whether future recruitment levels are within the bounds projected by the operating models.

Probably only the entries under 2) need revision, as they embellish what seem a sufficient set of non-exhaustive examples given under 1). Some technical updates are/maybe necessary here. For example:

- selectivity is now modelled as length-specific in the operating models
- the exact probability levels (95 or 99%?) and models to be used (RSa and RSb?) to be used to define the "bounds" mentioned above should perhaps be specified
- given that the revision process has concentrated on attaining adequate recovery of *M. paradoxus* under RSa, and achieves only broad stability for a depleted *M. capensis* population under RSb, provisions for keeping updates of this scenario under review might be mentioned
- consideration needs to be given to including a "survey-CPUE discrepancy statistic" as suggested below

This statistic is defined for each species as:

$$D_y^{WC\_surv,spp} = \Delta I_y^{WC\_surv,spp} - \frac{\left(\Delta I_y^{WC\_CPUE,spp} + \Delta I_y^{SC\_CPUE,spp}\right)}{2}$$

$$D_y^{SC\_surv,spp} = \Delta I_y^{SC\_surv,spp} - \frac{\left(\Delta I_y^{WC\_CPUE,spp} + \Delta I_y^{SC\_CPUE,spp}\right)}{2} \qquad (5)$$

where

$$\Delta I_y^i = \frac{\left(I_{y+1}^i - I_y^i\right)}{I_y^i}$$

Fig. 4 contrasts past values for this statistic with distributions projected under projections of RSa for CMPf1a.

<u>Reference Points</u>

The MSC condition for specification of Target and Limit Reference Points for *M. paradoxus* is probably best handled by adding appropriate words to section 2) of the document. Given that the MSC's particular focus is on the status of *M. paradoxus* in terms of abundance, it is suggested that the document recognise the following agreed Reference Points, defined in terms of the RSa set of operating models (or RS1 in years where only the Reference Case assessment is updated:

- Target – B^{sp}_{MSY}
- Limit – B^{sp}_{2007} (a low point on the trajectory)

Projected probabilities of exceeding these and related Reference Points under CMPf1a in future years are shown in Fig. 5. Thus perhaps a bullet that exceptional circumstances be considered if updated assessments fail to show a probability of B^{sp} in excess of 1.2 B^{sp}_{2007} that increases from 20% in 2007 to 70% in 2016 might be considered.

Suggestions for the Way Forward

The coming DWG meeting first needs to agree on a small subset of CMPs to be subjected to the full set of robustness trials before a selection is made amongst them at the following meeting as the recommended revised hake OMP. (Note here that "amongst" includes the possibility of a selection intermediate between the variants tested, i.e. interpolation but not extrapolation is permitted.)

The suggested subset is:

- CMPf1c, CMPf1b and CMPf1a (i.e. tunings to median average TACs over the next decade of 127, 132 and 137 thousand tons)
- Variants of the three CMPs above for which the maximum inter-annual TAC reduction is set at 10% rather than 5% (unless the "penalty" term of equation (1) becomes operative), tuned to the same median average TACs as above.

The full set of robustness tests would be conducted only for CMPf1c and CMPf1a. Only if there was failure in terms of risk statistics for the more "aggressive" CMPf1a, would the tests concerned be repeated for less aggressive CMP options (CMPf1b, or CMPf1a with the downward inter-annual TAC constraint increased from 5 to 10%.

One caveat is that before proceeding with CMPf1c and CMPf1b as currently specified, investigation would be conducted to see whether the p^{spp} control parameters for those CMPs (see Table 1b) might be decreased from 0.75 to improve the "lowest TAC" statistic under RS1/RSa while still achieving similar performance to CMPf1a for the lower 2.5%ile envelope for B^{sp} for Rob13 (see Fig. 2a).

Equivalent risk tunings of CMPs given the imposition of MPAs have not yet been completed for all the potential impacts on CPUE considered, and the DWG might wish to set further selections/specifications for that exercise.

Finally, as any revisions to the *"Procedures for Deviating from the hake OMP output for the recommendation for a TAC, and for initiating an OMP review"* document will need to be finalised at the following DWG meeting, further calculations that might be needed to assist that process need to be agreed at the coming meeting.

Reference

Rademeyer RA and Butterworth DS. 2010. Further Candidate Management Procedure testing for the South African hake resource. Unpublished report, Marine and Coastal Management, South Africa. FISHERIES/2010/AUGUST/SWG-DEM/37.

Table 1a: Summary of the CMPs tested.

CMP	Description
C=119.8	catch = 119 800t, the 2010 TAC
CMP2006	OMP2006
CMPc1a	Base Case c, tuned to average catch of 135 000t over 2011-2020
CMPf1a	**Base Case f**, tuned to average catch of **137 000t** over 2011-2020
CMPf1b	**Base Case f**, tuned to average catch of **132 000t** over 2011-2020
CMPf1c	**Base Case f**, tuned to average catch of **127 000t** over 2011-2020
CMPf2a	As **Base Case f**, p^{cap}=0.85 instead of 0.75
CMPf3a	As **Base Case f**, no extra penalty
CMPf4a	As **Base Case f**, p^{para}=0.6 and p^{cap}=0.6

Table 1b: Tuning parameter values for each CMP presented. T^{para} applies up to the year 2015 and then declines linearly to zero in year 2018.

CMP	$\square_{up}$	$\square_{down}$	T^{para}	T^{cap}	w	a^{para}	a^{cap}	b^{para}	b^{cap}	c^{para}	c^{cap}	p^{para}	p^{cap}	Q_{min}	Annual change constraints	
C=119.8																
CMP2006	0.5-1.1	1.1-2.0	2.40%	0											+10%	-10%
CMPc1a	1.25	1.50	1.00%	0	1-0.5	105.8	40.0	60.0	20.0						+10%	-10%
CMPf1a	1.25	1.50	0.50%	0	1-0.5	114.3	40.0	60.0	20.0	180	20	0.75	0.75	0.75	+10%	-5%*
CMPf1b	1.25	1.50	0.75%	0	1-0.5	104.5	40.0	60.0	20.0	180	20	0.75	0.75	0.75	+10%	-5%*
CMPf1c	1.25	1.50	1.00%	0	1-0.5	94.7	40.0	60.0	20.0	180	20	0.75	0.75	0.75	+10%	-5%*
CMPf2a	1.25	1.50	0.50%	0	1-0.5	114.3	40.0	60.0	20.0	180	20	0.75	0.85	0.75	+10%	-5%*
CMPf3a	1.25	1.50	0.50%	0	1-0.5	114.3	40.0	60.0	20.0						+10%	-5%
CMPf4a	1.25	1.50	0.50%	0	1-0.5	111.7	40.0	60.0	20.0	180	20	0.60	0.60	0.75	+10%	-5%*

* can change up to -25% following equation (4)

Table 2: Projections results (either median or lower 2.5%ile) for a series of performance statistics for different CMPs under the RS. This Table focuses in particular on the new Reference Case (CMPf1) and its three tunings (CMPf1a/b/c).

			C=119.8	OMP2006	CMPc1a	CMPf1a	CMPf1b	CMPf1c
		RSa						
median	BS	avC: 2011-2020	119.8	127.4	**135.0**	**137.0**	132.0	127.0
low	para	$B^{sp}_{low}/B^{sp}_{2010}$	0.73	0.72	**0.72**	**0.71**	0.72	0.73
low	cap	$B^{sp}_{low}/B^{sp}_{2010}$	0.79	0.72	**0.75**	**0.75**	0.77	0.78
median	para	B^{sp}_{2020}/B_{MSY}	1.46	1.30	**1.12**	**1.11**	1.20	1.29
median	cap	B^{sp}_{2020}/B_{MSY}	2.98	2.93	**2.89**	**2.87**	2.90	2.93
median	BS	AAV	0.0	4.2	**3.4**	**3.6**	3.5	3.5
low	BS	lowest TAC (2011-2030)	119.8	88.7	**104.0**	**94.5**	91.9	87.8
		RSb						
median	BS	avC: 2011-2015	119.8	122.0	**129.8**	**130.5**	125.6	120.6
low	para	$B^{sp}_{low}/B^{sp}_{2010}$	0.95	0.95	**0.93**	**0.93**	0.93	0.93
low	cap	$B^{sp}_{low}/B^{sp}_{2010}$	0.87	0.88	**0.82**	**0.80**	0.85	0.87
median	para	B^{sp}_{2020}/B_{MSY}	1.03	1.04	**0.91**	**0.89**	0.96	1.04
median	cap	B^{sp}_{2020}/B_{MSY}	0.60	0.60	**0.55**	**0.55**	0.57	0.60
median	BS	AAV	0.0	4.3	**3.2**	**3.5**	3.4	3.6
low	BS	lowest TAC (2011-2030)	119.8	87.1	**102.7**	**86.1**	84.5	75.3

Table 2b: Year in which the *M. paradoxus* spawning biomass is expected (in median terms) to first exceed B_{MSY} for a series of CMPs for RSa. OMP2006* is as applied in 2006 (i.e. to the 2006 RS), while OMP2006 has been run under the current RSa.

	Year *M. paradoxus* biomass > Bmsy
C=119.8	2015
OMP2006*	2024
OMP2006	2016
CMPc1a	2017
CMPf1a	2017
CMPf1b	2017
CMPf1c	2016

Table 3a: Projections results (either median or lower 2.5%ile) for a series of performance statistics for CMPf1a for a series of more severe robustness tests related to *M. paradoxus* (Rob5 (True Ricker), Rob13 (decrease in *K* in the past), Rob17 (start in 1978), Rob25 (lower steepness *h*), Rob31f (case of no survey and an undetected catchability trend for CPUE in the future - the surveys are used in the computation of the slope until more than two data points (out of six) are missing for the regression.), Rob35 (undetected catchability trend for CPUE in the future) and Rob37 (future decrease in *K*)) under RSa.

			Based on RS1 only					Based on RSa			
CMPf1a		**RSa**	RS1	Rob5	Rob13	Rob17	Rob25	RSa	Rob31f	Rob35	Rob37
median	BS	avC: 2011-2020	138.2	130.9	87.9	155.2	115.2	137.0	153.9	141.4	135.6
low	para	$B^{sp}_{low}/B^{sp}_{2010}$	0.83	0.69	0.27	0.80	0.53	0.71	0.43	0.64	0.41
low	cap	$B^{sp}_{low}/B^{sp}_{2010}$	0.98	0.96	1.02	0.82	1.07	0.75	0.72	0.74	0.34
median	para	B^{sp}_{2020}/B_{MSY}	1.05	0.80	0.72	1.06	0.58	1.11	0.80	1.03	1.33
median	cap	B^{sp}_{2020}/B_{MSY}	2.41	2.00	2.12	1.90	2.11	2.87	2.81	2.86	3.82
median	BS	AAV	3.5	3.5	7.6	4.3	4.5	3.6	4.1	3.7	5.8
low	BS	lowest TAC (2011-2030)	105.6	97.1	30.9	119.3	69.4	94.5	113.8	103.6	36.1

Table 3b: Projections results (either median or lower 2.5%ile) for a series of performance statistics for a for a series of more severe robustness tests under RSb (related to *M. capensis*).

			Based on RS11 only				
CMPf1a		**RSb**	RS11	Rob5	Rob13	Rob25	Rob37
median	BS	avC: 2011-2020	130.6	132.0	90.0	128.9	128.9
low	para	$B^{sp}_{low}/B^{sp}_{2010}$	0.93	1.00	0.38	0.78	0.78
low	cap	$B^{sp}_{low}/B^{sp}_{2010}$	0.84	0.75	0.92	0.69	0.69
median	para	B^{sp}_{2020}/B_{MSY}	0.89	0.78	0.99	1.10	1.10
median	cap	B^{sp}_{2020}/B_{MSY}	0.58	0.52	2.85	0.74	0.74
median	BS	AAV	3.5	3.4	8.2	4.4	4.4
low	BS	lowest TAC (2011-2030)	87.2	96.0	36.5	61.5	61.5

Table 4: Projections results (either median or lower 2.5%ile) for a series of performance statistics for CMPf1a (p^{para}=0.75, p^{cap}=0.75) and variants thereof: CMPf2a (p^{cap}=0.85), CMPf3a (no penalty) and CMPf4a (p^{para}=0.6, p^{cap}=0.6) for RS1 and robustness test Rob13 (decrease in *K* in the past).

			RS1				Rob13			
		RSa	CMPf1a	CMPf2a	CMPf3a	CMPf4a	CMPf1a	CMPf2a	CMPf3a	CMPf4a
median	BS	avC: 2011-2020	138.2	138.2	139.7	138.3	87.9	87.9	108.4	93.4
low	para	$B^{sp}_{low}/B^{sp}_{2010}$	0.83	0.83	0.82	0.83	0.27	0.27	0.00	0.06
low	cap	$B^{sp}_{low}/B^{sp}_{2010}$	0.98	0.98	0.98	0.99	1.02	1.02	0.00	1.02
median	para	B^{sp}_{2020}/B_{MSY}	1.05	1.05	1.01	1.04	0.72	0.72	0.21	0.58
median	cap	B^{sp}_{2020}/B_{MSY}	2.41	2.41	2.40	2.42	2.12	2.12	1.64	2.01
median	BS	AAV	3.5	3.5	3.3	3.3	7.6	7.6	3.7	6.8
low	BS	lowest TAC (2011-2030)	105.6	105.6	114.9	107.5	30.9	30.9	71.2	33.5

Table 5: Projections results (either median or lower 2.5%ile) for a series of performance statistics for CMPf1a for RSa and a series of robustness tests related to the intensities of future surveys (Rob31a: no surveys; Rob31b: only WC surveys; Rob31c: only SC surveys; Rob31d: both surveys missing every 3 years; Rob31e: increase all future surveys CVs by multiplicative factor of sqrt(2); Rob31f: no surveys plus undetected increase catchability related to CPUE; Rob31 g: both surveys missing every 2 years; Rob35. undetected increase catchability related to CPUE). For Rob31g, CMPf1a has been first tuned to the same "low para" for RSa ("tuned to risk"). In cases of missing surveys, the surveys are used in the computation of the slope until more than three data points (out of six) are missing for the regression).

CMPf1a			RSa	Rob31a	Rob31b	Rob31c	Rob31d	Rob31e	Rob31f	Rob31g	Rob31g tuned to risk	Rob35
median	BS	avC: 2011-2020	137.0	149.1	146.5	120.0	138.9	138.9	153.9	139.5	132.1	141.4
low	para	$B^{sp}_{low}/B^{sp}_{2010}$	0.71	0.54	0.58	0.96	0.69	0.70	0.43	0.69	0.71	0.64
low	cap	$B^{sp}_{low}/B^{sp}_{2010}$	0.75	0.78	0.79	1.16	0.76	0.75	0.72	0.76	0.78	0.74
median	para	B^{sp}_{2020}/B_{MSY}	1.11	0.87	0.93	1.58	1.09	1.09	0.80	1.08	1.22	1.03
median	cap	B^{sp}_{2020}/B_{MSY}	2.87	2.83	2.84	2.99	2.88	2.87	2.81	2.88	2.92	2.86
median	BS	AAV	3.6	4.1	3.8	8.0	3.8	3.6	4.1	4.0	4.3	3.7
low	BS	lowest TAC (2011-2030)	94.5	99.5	100.2	87.3	92.2	96.5	113.8	91.2	84.4	103.6

Table 6: Projections results (either median or lower 2.5%ile) for a series of performance statistics for CMPf1a for RSa and a series of robustness tests related to the implications of impact on CPUE through the introductions of MPAs (Rob33a: no CPUE; Rob33b: new CPUE with prior on q; Rob33c: new CPUE with lower q and Rob33d: new CPUE with higher q). For Rob33d, CMPf1a has been retuned to give the same risk as for RSa (Rob33d*). In case of no future CPUE, the CPUEs are used in the computation of the slope until more than two data points (out of six) are missing for the regression).

CMPf1a			RSa	Rob33a	Rob33b	Rob33c	Rob33d	Rob33d*
median	BS	avC: 2011-2020	137.0	147.2	192.7	124.9	147.8	123.3
low	para	$B^{sp}_{low}/B^{sp}_{2010}$	0.71	0.48	0.12	0.74	0.55	0.71
low	cap	$B^{sp}_{low}/B^{sp}_{2010}$	0.75	0.82	0.12	0.74	0.76	0.80
median	para	B^{sp}_{2020}/B_{MSY}	1.11	0.89	0.57	1.36	0.88	1.34
median	cap	B^{sp}_{2020}/B_{MSY}	2.87	2.83	2.64	2.94	2.82	2.94
median	BS	AAV	3.6	6.3	7.7	4.0	3.9	3.8
low	BS	lowest TAC (2011-2030)	94.5	59.4	90.5	74.2	108.0	86.8

Table 7: Projections results (either median or lower 2.5%ile) for a series of performance statistics for CMPf1a for RobOLRAC.

				Based on RS11
CMPf1a			RS11	RobOLRAC
median	BS	avC: 2011-2020	130.6	171.3
low	para	$B^{sp}_{low}/B^{sp}_{2010}$	0.93	0.85
low	cap	$B^{sp}_{low}/B^{sp}_{2010}$	0.84	0.95
median	para	B^{sp}_{2020}/B_{MSY}	0.89	1.76
median	cap	B^{sp}_{2020}/B_{MSY}	0.58	4.45
median	BS	AAV	3.5	4.7
low	BS	lowest TAC (2011-2030)	87.2	131.8

Table 8: Projections results (either median or lower 2.5%ile) for a series of performance statistics for CMPc1a, CMPc1aJ* and CMPc1aJ* 3x λ for the RS, where the last two based TAC changes on the average TAC for the last five years.

			CMPc1a	CMPc1aJ* tuned to risk	CMPc1aJ* tuned to risk 3x λ
		RSa			
median	BS	avC: 2011-2020	135.0	**126.4**	128.1
low	para	$B^{sp}_{low}/B^{sp}_{2010}$	0.72	**0.72**	0.72
low	cap	$B^{sp}_{low}/B^{sp}_{2010}$	0.75	**0.75**	0.77
median	para	B^{sp}_{2020}/B_{MSY}	1.12	**1.32**	1.25
median	cap	B^{sp}_{2020}/B_{MSY}	2.89	**2.94**	2.92
median	BS	AAV	3.4	**3.1**	6.0
low	BS	lowest TAC (2011-2030)	104.0	**103.6**	89.3
		RSb			
median	BS	avC: 2011-2015	129.8	**122.9**	124.9
low	para	$B^{sp}_{low}/B^{sp}_{2010}$	0.93	**0.93**	0.92
low	cap	$B^{sp}_{low}/B^{sp}_{2010}$	0.82	**0.87**	0.89
median	para	B^{sp}_{2020}/B_{MSY}	0.91	**1.02**	1.00
median	cap	B^{sp}_{2020}/B_{MSY}	0.55	**0.58**	0.58
median	BS	AAV	3.2	**3.1**	5.7
low	BS	lowest TAC (2011-2030)	102.7	**103.0**	88.7

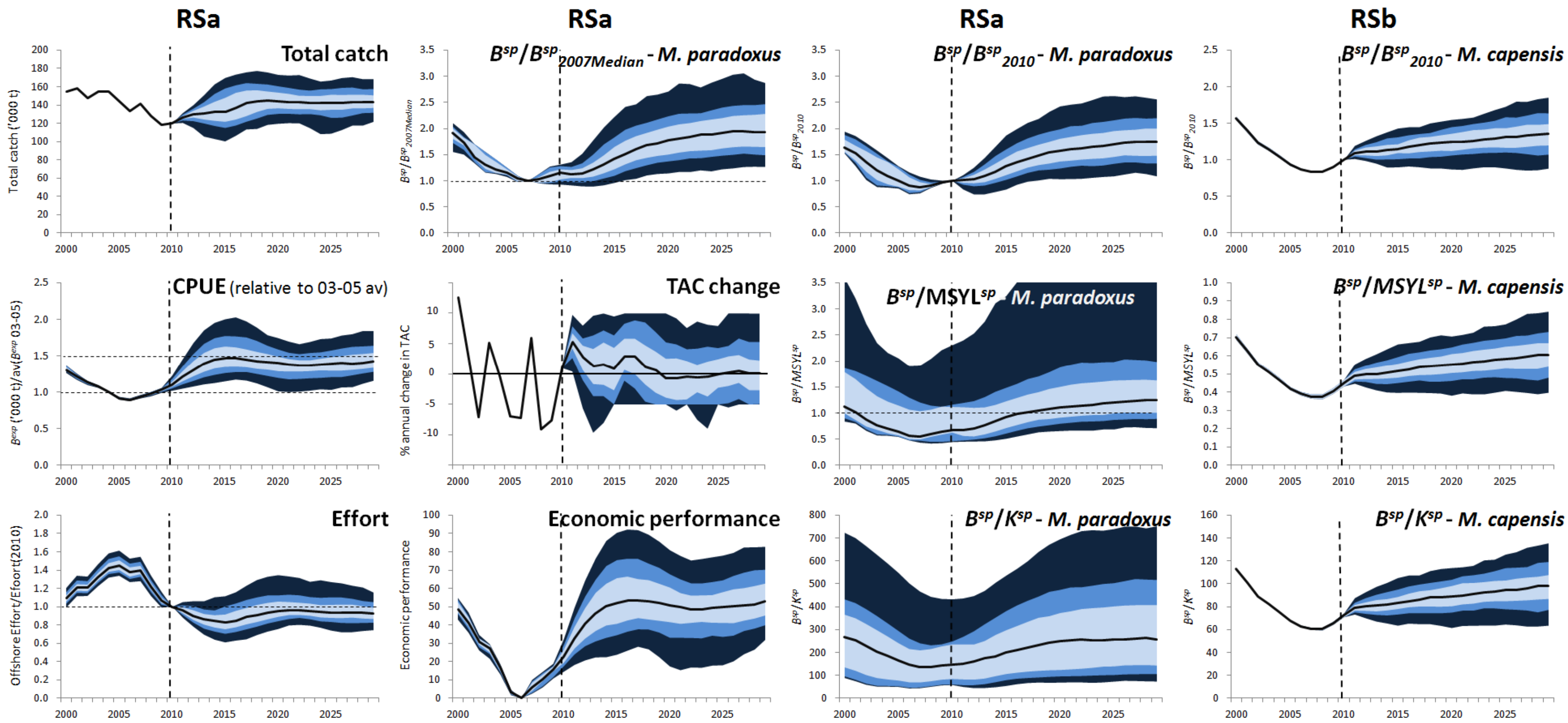


Fig. 1a: 95, 75, 50% PI and median for a series of performance statistics for **CMPf1a**.

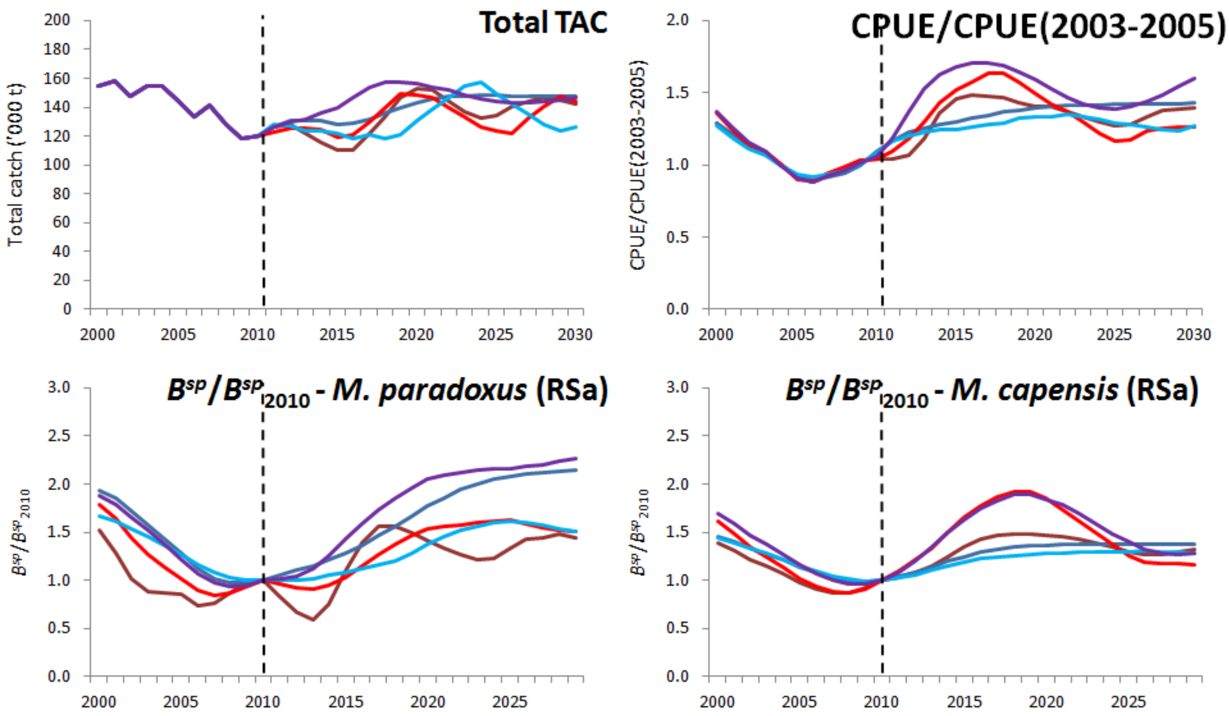


Fig. 1b: Worm plots of TAC, CPUE and B^{sp}/B^{sp}_{2010} for *M. paradoxus* and *M. capensis* under RSa for **CMPf1a**.

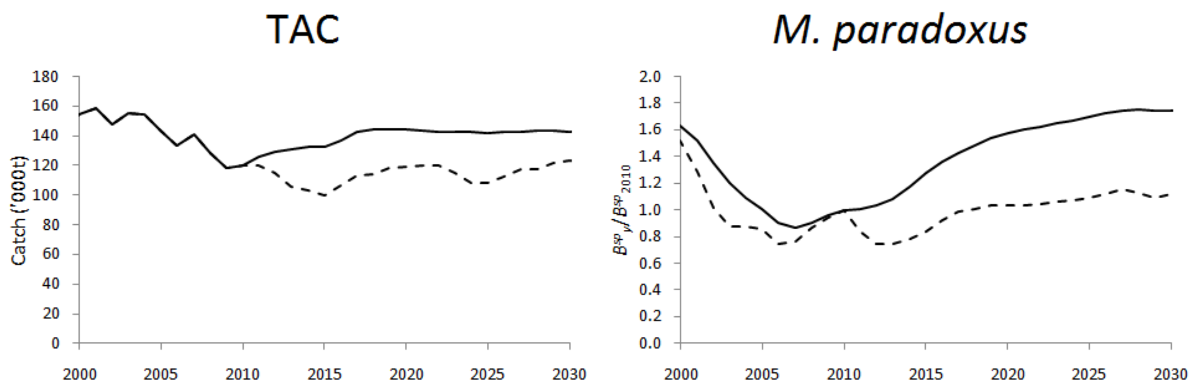


Fig. 1c: Median (full line) and lower 2.5%iles (dashed line) TAC and spawning biomass (in terms of 2010 level) for *M. paradoxus* for RSa under CMPf1a.

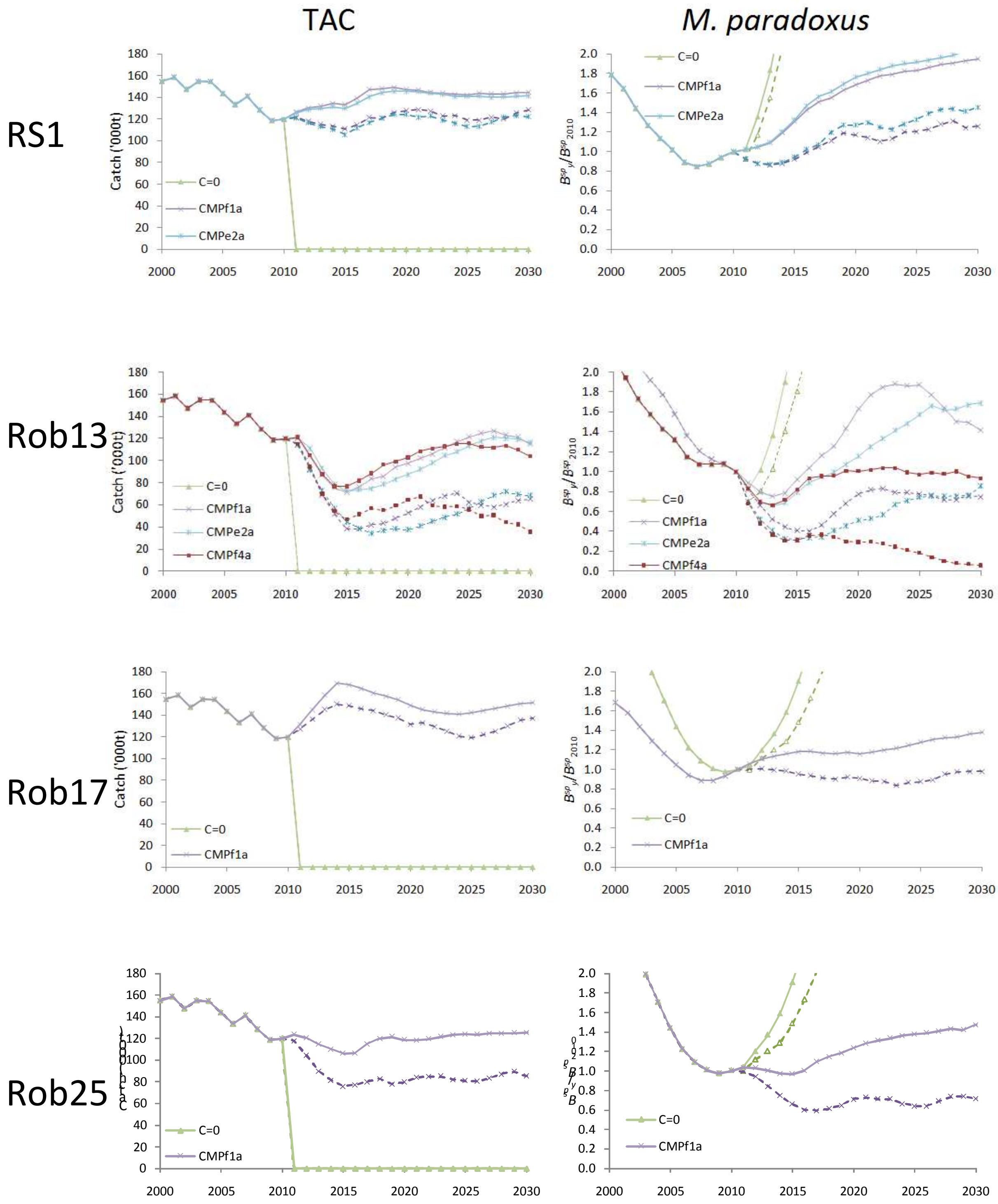


Fig. 2a: Median (full lines) and lower 2.5%iles (dashed lines) TAC and spawning biomass (in terms of 2010 level) for *M. paradoxus* for a series of CMPs and different robustness tests based on RS1 (Rob5 (True Ricker), Rob13 (decrease in *K* in the past), Rob17 (start in 1978) and Rob25 (lower steepness *h*)).

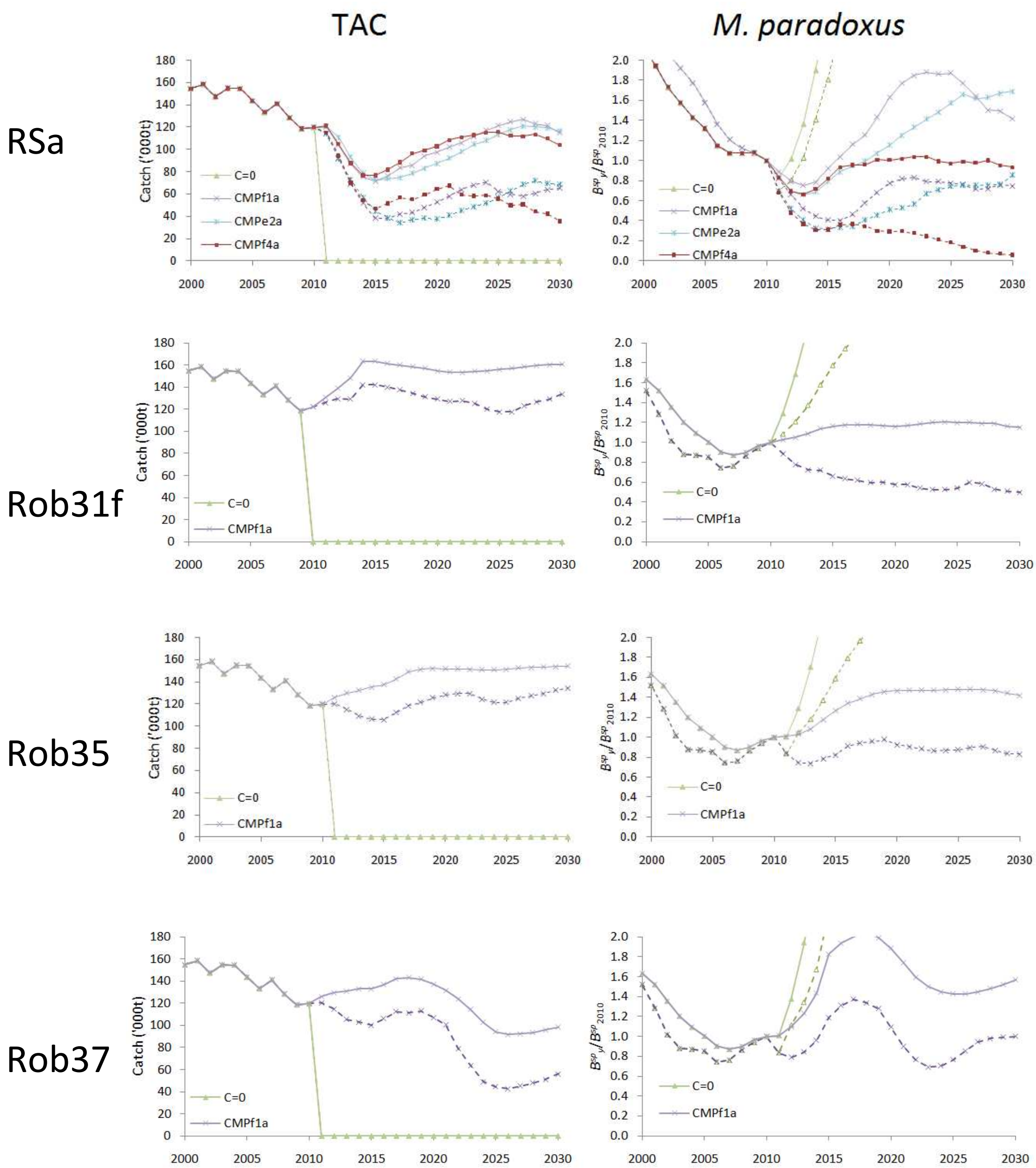


Fig. 2b: Median (full lines) and lower 2.5%iles (dashed lines) TAC and spawning biomass (in terms of 2010 level) for *M. paradoxus* for a series of CMPs and different robustness tests based on RSa (Rob31f (case of no survey and an undetected catchability trend for CPUE), Rob35 (undetected catchability trend for CPUE) and Rob37 (decrease in *K*)).

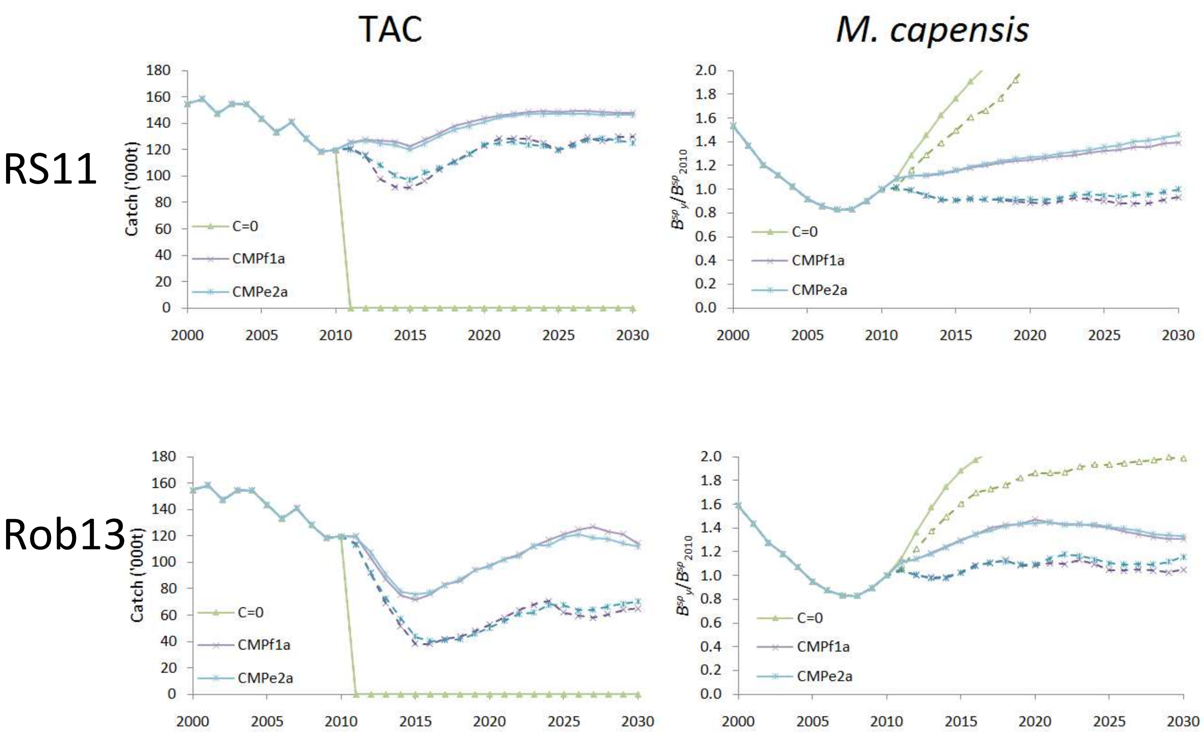


Fig. 2c: Median (full lines) and lower 2.5%iles (dashed lines) TAC and spawning biomass (in terms of 2010 level) for *M. capensis* for a series of CMPs for RS11 (decrease in *K*) and Rob13 based on RS11.

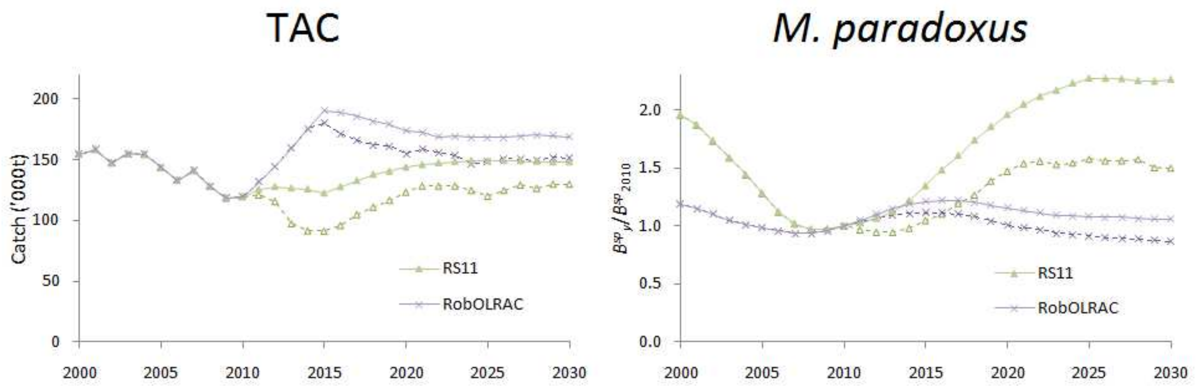


Fig. 2d: Median (full lines) and lower 2.5%iles (dashed lines) TAC and spawning biomass (in terms of 2010 level) for *M. paradoxus* for RS11 and RobOLRAC under CMPf1a.

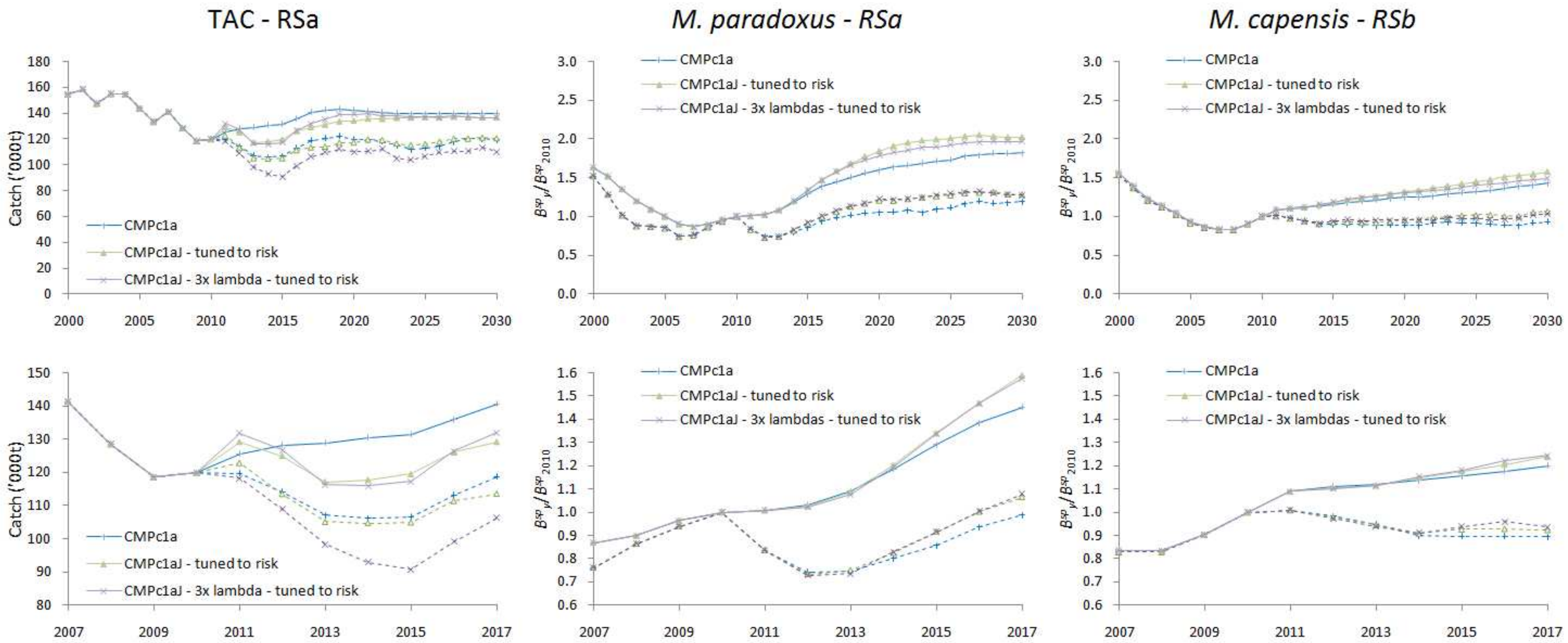
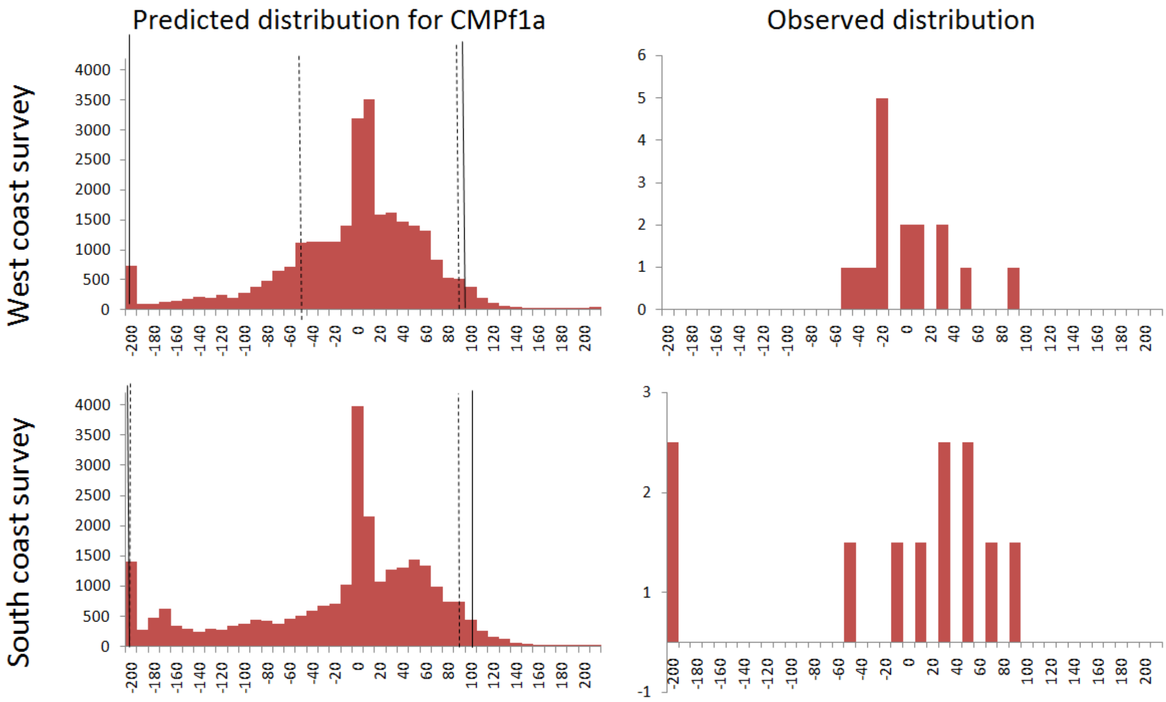


Fig. 3: Median (full lines) and lower 2.5%iles (dashed lines) TAC (RSa) and spawning biomass (in terms of 2010 level) for *M. paradoxus* (RSa) and *M. capensis* (RSb) for the previous Reference Case CMP (CMPc1a) and two variants which make TAC changes based on the average TAC for the last five years rather than the TAC for the last year.

M. paradoxus



M. capensis

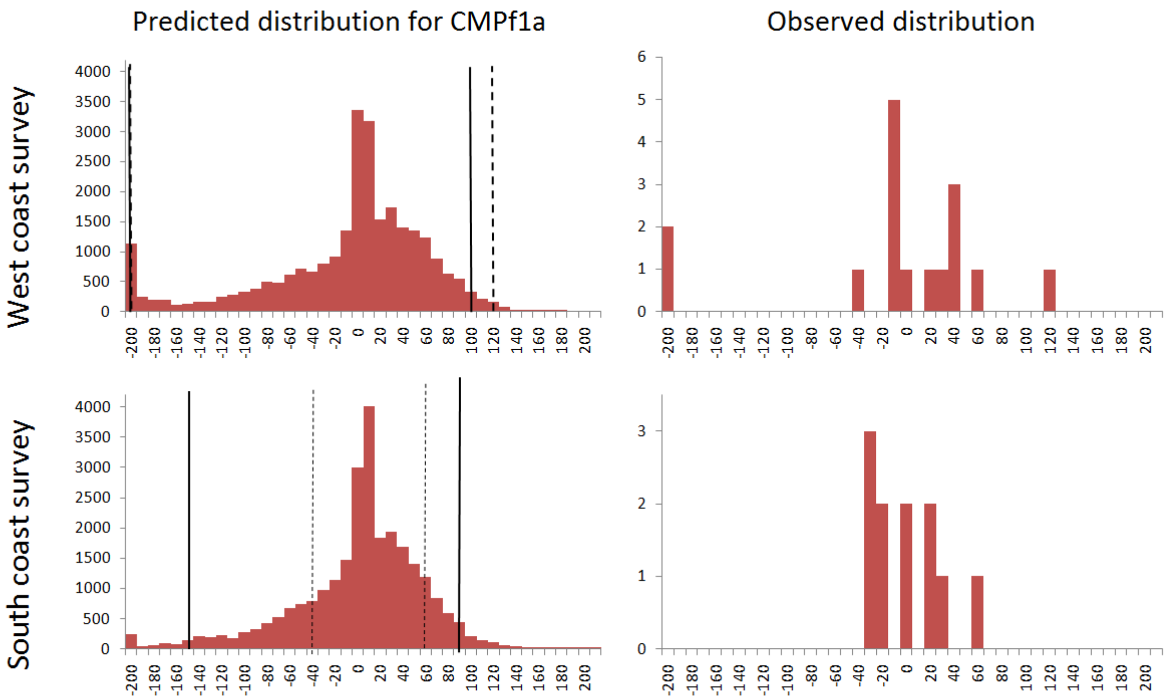


Fig. 4: Predicted (under CMPf1a, for RSa) and past observed distributions of the discrepancy statistic (equation 5) for *M. paradoxus* and *M. capensis.* For the predicted distributions, the dashed vertical lines indicate the extent of past observed discrepancies, while the solid vertical lines show the lower and upper 2.5%iles of the predicted distributions.

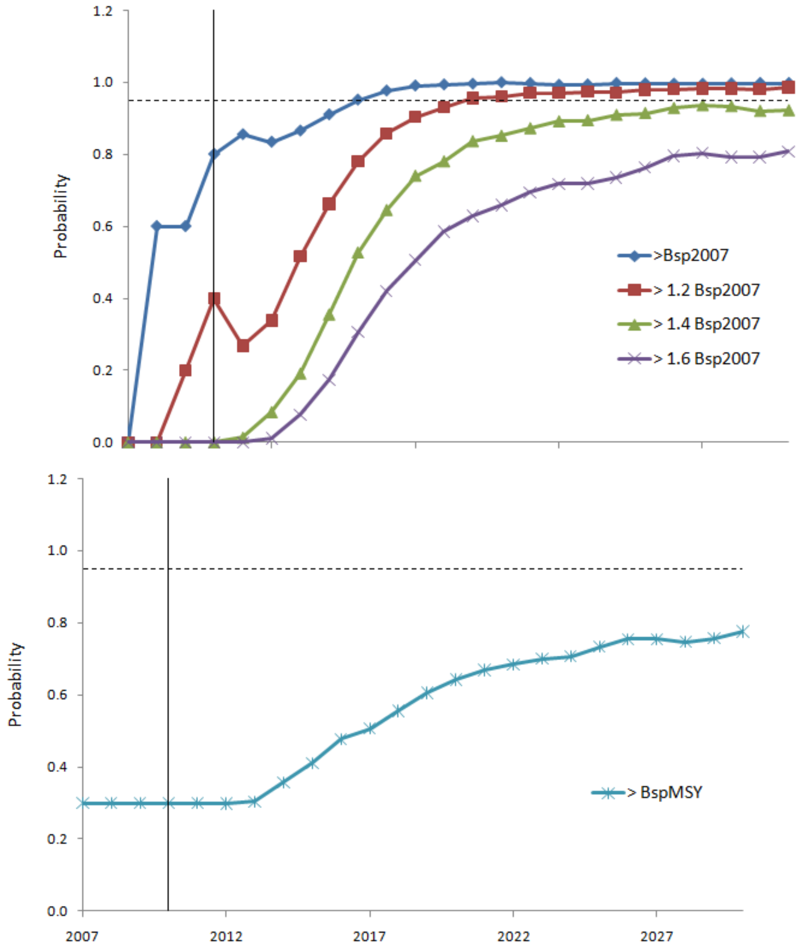


Fig. 5: Time trajectories uncer CMPf1aof the probability that the *M. paradoxus* spawning biomass is above a potential Limit Reference Point (top plot) and the probability that the *M. paradoxus* spawning biomass is above a potential Target Reference Point, under CMPf1a (bottom plot) for RSa.