Yet Further CMP Projections for the South African hake resource

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Introduction

This document addresses issues raised at and outstanding from the previous discussions of the hake OMP revision at the DWG meeting on 26 August, and concludes by listing issues still requiring choices/analyses to be able to finalise this OMP revision process at the next DWG meeting on 13 October.

Precision of the Base Risk statistic

Standard errors have been computed (by estimating variance for results across subsets of the existing simulations) for the Base Risk statistic, defined as the lower (2.5 or 5) percentile of the *M. paradoxus* spawning biomass in 2024 relative to MSYL. The standard errors are about 2% (for both the 2.5 and 5%iles), given the current number of 1100 simulations (100 simulations for each of the 11 OMs in the RS).

This result does not lend support the concerns raised at the last DWG meeting that the lower 2.5 percentile estimate is less reliable than, say, the lower 5 percentile as the basis for comparing CMP performance for equivalent resource risk levels. Nevertheless, given those concerns expressed, “Base Risk” in this document has been taken to correspond to the lower 5 percentile of the *M. paradoxus* spawning biomass in 2024 relative to MSYL.

5% vs 10% maximum interannual TAC change constraint

The impact of a maximum interannual TAC change constraint of 5% vs. 10% per annum has been found to be minimal for the 135 000t and 140 000t 2015-2024 average catch tunings (see Table 1 and Figures 1 and 2). The small task group appointed at the last DWG meeting therefore decided to keep to the *status quo* of the 10% constraint.

"Safeguard" rule

As seen in Rademeyer and Butterworth (2014), CMP2a does not perform well in some of the more severe robustness tests (involving changes in carrying capacity over time), because of the 5% constraint on the maximum interannual decrease in TAC. In CMP5, the constraint on the maximum interannual TAC change is weakened if the *M. paradoxus* average biomass index falls too low:

$$MaxDecr_y = \begin{cases} 5\% & \text{if } J_{\text{y}} \geq J^{thresh1} \\ \text{linear between x\% and 5\%} & \text{if } J^{thresh2} \leq J_{\text{y}} < J^{thresh1} \\ \text{x\%} & \text{if } J_{\text{y}} < J^{thresh2} \end{cases} \quad (1)$$

Results for two CMPs with this extra safeguard rule are presented in Table 2 and Figures 3 and 4. For $CMP5a_{135}$, $J^{thresh1}$=0.8, $J^{thresh2}$=0.6 and *x*=20%. For $CMP5b_{135}$, the safeguard rule kicks in at a lower threshold ($J^{thresh1}$=0.75), but is then more severe ($J^{thresh1}$=0.65 and *x*=25%).

Table 2 and Figure 3 indicate that (as would be desired) neither safeguard rule has much effect on performance under the RS. For the robustness test (C.future.5) of a future decrease in *K* (specifically a 20% linear decrease in *K* for both species between 2015 and 2020, and based on the full RS), these safeguards are successful at recovering the *M. paradoxus* spawning biomass at the lower 5 percentile, when compared to $CMP2a_{135}$ which does not include the safeguard rule (Figure 4).

Given these results, further CMP comparisons in this document have used $CMP5a_{135}$ as a baseline. However there could be reason for eventually selecting $CMP5b_{135}$ instead, because it runs less risk of a low TAC at the 5 percentile level under the RS (Figure 3) in the short term, while achieving slightly better recovery of the *M paradoxus* resource for the C.future.5 robustness test (Figure 4).

Fixed TAC in 2015 and 2016 to 147 500t

In Rademeyer and Butterworth (2014), the CMP fixing the 2015 and 2016 TACs to 147 500t involved increasing the maximum downward constraint on the interannual TAC change from 5% to 6% to comply with the Base Risk requirement. Here, results are presented for a CMP with a fixed TAC of 147 500t for the next two years and including the safeguard rule (as in $CMP5a_{135}$), so that the default downward constraint (5%) is not changed. This CMP ($CMP6a_{BR5}$) is tuned to the Base Risk. Results are given in Table 3 and Figure 5.

$CMP6a_{BR5}$ does result in likely higher TACs in the short term, but over the next 10 years there is a drop of about 3 000t in the average annual catch (i.e. less initial "pain" replaced by yet greater later "pain").

Future surveys conducted by industry vessels

The impact of having future surveys conducted by industry vessels is evaluated by taking that the catchability coefficient q_y^{induV} for the industry to be either 20% or 40% greater than that of the *Africana* with the new gear:

$q_y^{induV} = 1.2q^{Africana}$ or $q_y^{induV} = 1.4q^{Africana}$

The same *q* ratio is used for both surveys (summer and autumn) and both species.

Results are shown in Table 4 and Figure 6 under $CMP5a_{135}$ (not tuned) and $CMP5a_{BR5}$, which has been tuned to the Base Risk.

As might be expected, if an industry vessel's *q* is higher, average annual catch increases (by about 5 000t), with a compensatory loss in median recovery of *M. paradoxus* (of about 10% of MSYL), for each 20% by which the *q* is higher (Table 4).

Looked at another way, if the CMP is precautionarily retuned to allow for a possible 20% higher industry vessel *q* ($CMP5a_{BR5}$), the resultant performance when this is actually the case is near identical to that for the baseline $CMP5a_{135}$ under the RS. However if in fact the industry vessel had the same *q* as the

Africana, this "mistake" results in a loss in annual average catch which is about 6 500t over the next ten years (see respectively the last two columns in Table 4).

At the December 2013 International Workshop, a decision was made to assume that the ratio of the catchabilities for an industry vessel and *Africana* has a CV of 20%. The choice to show results for a fixed 20% in this document was made in the light of that CV to give some initial sense of "how bad" could the consequences be of either ignoring the possibility of a difference in catchabilities, or of precautionarily allowing for this, but incorrectly so. Possible further computations might wish to re-evaluate these results for some distribution of the extent of the possible catchability difference.

Undetected increase in CPUE

Results for the robustness test C.future.3 which projects under an undetected increase in CPUE catchability of 2% per annum are given in Table 5 and Figure 7. Results for this robustness test in combination with a future surveys being carried out by an industry vessel with a *q* 20% higher than for the *Africana* are also shown.

Essentially $CMP5a_{135}$ seems to behave reasonably even if there is such a bias CPUE catchability, with the Base Risk of 0.66 dropping only to 0.63. Even given an unrealized industry survey vessel catchability increase of 20% compared to *Africana*, CMP performance is not too heavily compromised.

Towards completion of the OMP revision

At this stage the baseline CMP candidate (assumed above) is $CMP5a_{135}$. A recommendation for a selection of the revised OMP needs to be made at the next DWG meeting planned for 13 October. At this meeting it would seem that the DWG needs to either or both narrow the options and specify final computations in regard to the following.

- The basic tuning level – an anticipated average annual catch somewhere between 135 and 140 000t
- The basic interannual TAC change constraint – maximum upward change of 10% (the baseline here) or 5%?
- The "safeguard rule" choice – whether $CMP5a_{135}$ or $CMP5b_{135}$?
- Whether to choose an option which fixes the TAC for the next two years (at 147 500t)?
- Is the assumption to be made that *Africana* will be available for future surveys, or if not is some precautionary adjustment to be made for the possibility that industry vessels are used and happen to have higher survey catchabilities though this is not realised?
- Is allowance to be made for inshore hake quota allocations being moved offshore?
- Robustness tests – do any further need to be run? – though a final analysis should check more widely, it would seem that $CMP5a_{135}$ shows adequate performance for the tests conducted to date (which include the change in *K* trials, which for OMP2010 proved the most "difficult" of these tests).
- Any other factors to consider?

Reference

Rademeyer, RA and Butterworth, DS. 2014. Further Candidate Management Procedures projections for the South African hake resource. Document FISHERIES/2014/AUG/SWG-DEM/41. 28pp.

Table 1: Median and 95% PIs for a series of performance statistics under the RS, for $CMP2a_{135}$, $CMP2a_{140}$ (both with **10% upward constraint**) and two equivalent CMPs with **5% upward constraint** ($CMP4a_{140}$ and $CMP4a_{135}$).

MP:		+10% constraint $CMP2a_{135}$		+5% constraint $CMP4a_{135}$		+10% constraint $CMP2a_{140}$		+5% constraint $CMP4a_{140}$	
C_{2014}		**155.3**		**155.3**		**155.3**		**155.3**	
C_{2015}	BS	147.5	(147.5; 150.0)	147.5	(147.5; 150.0)	147.5	(147.5; 150.0)	147.5	(147.5; 150.0)
C_{2016}	BS	140.1	(140.1; 144.8)	140.1	(140.1; 148.4)	140.1	(140.1; 150.0)	140.1	(140.1; 150.0)
C_{2017}	BS	133.1	(133.1; 150.0)	133.1	(133.1; 150.0)	133.1	(133.1; 150.0)	133.8	(133.1; 150.0)
B^{sp}_{2014}/B_{MSY}	para	0.83	(0.63; 1.26)	0.83	(0.63; 1.26)	0.83	(0.63; 1.26)	0.83	(0.63; 1.26)
B^{sp}_{2015}/B_{MSY}	para	0.74	(0.59; 1.09)	0.74	(0.59; 1.09)	0.74	(0.59; 1.09)	0.74	(0.59; 1.09)
B^{sp}_{2016}/B_{MSY}	para	0.68	(0.52; 1.08)	0.68	(0.52; 1.08)	0.68	(0.52; 1.08)	0.68	(0.52; 1.08)
B^{sp}_{2017}/B_{MSY}	para	0.68	(0.50; 1.23)	0.68	(0.50; 1.23)	0.68	(0.50; 1.23)	0.68	(0.50; 1.23)
avC: 2015-2024	BS	**135.0**	(119.3; 147.9)	**135.0**	(119.4; 148.5)	**140.0**	(121.6; 149.4)	**140.0**	(121.9; 149.6)
C_{low}: 2015-2034)	BS	116.4	(94.9; 135.4)	119.3	(96.5; 137.4)	122.2	(99.6; 142.0)	123.6	(100.4; 142.6)
AAV: 2015-2034	BS	0.04	(0.02; 0.05)	0.04	(0.01; 0.05)	0.03	(0.01; 0.05)	0.03	(0.01; 0.05)
$B^{sp}_{low}/B^{sp}_{2014}$	para	0.82	(0.53; 1.00)	0.81	(0.53; 1.00)	0.79	(0.53; 1.00)	0.79	(0.53; 1.00)
$B^{sp}_{low}/B^{sp}_{2014}$	cap	1.02	(0.75; 1.10)	1.02	(0.74; 1.10)	1.01	(0.73; 1.10)	1.00	(0.73; 1.10)
$B^{sp}_{low}/B^{sp}_{2007}$	para	1.35	(0.81; 1.66)	1.35	(0.81; 1.66)	1.32	(0.81; 1.65)	1.31	(0.81; 1.64)
$B^{sp}_{low}/B^{sp}_{2007}$	cap	1.68	(1.29; 1.91)	1.67	(1.29; 1.91)	1.66	(1.28; 1.90)	1.65	(1.27; 1.90)
B^{sp}_{2024}/B_{MSY}	para	1.06	(**0.64;** 2.16)	1.06	(**0.61;** 2.19)	0.97	(**0.55;** 2.00)	0.97	(**0.53;** 2.06)
90%iles			(**0.66;** 1.96)		(**0.65;** 1.97)		(**0.59;** 1.81)		(**0.58;** 1.84)
80%iles			(**0.71;** 1.79)		(**0.70;** 1.78)		(**0.65;** 1.63)		(**0.65;** 1.66)
B^{sp}_{2024}/B_{MSY}	cap	3.41	(1.75; 5.07)	3.41	(1.75; 5.09)	3.33	(1.70; 4.98)	3.32	(1.69; 4.98)
$CPUE_{2024}/CPUE_{2013}$	BS	1.11	(0.90; 1.40)	1.11	(0.89; 1.39)	1.08	(0.87; 1.35)	1.07	(0.86; 1.36)
E_{2024}/E_{2013}	BS	0.78	(0.60; 1.02)	0.78	(0.58; 1.01)	0.83	(0.65; 1.06)	0.83	(0.64; 1.07)
Prob decl >20% (2015-2017)		0.00		0.00		0.00		0.00	
Prob decl >20% (2016-2018)		0.00		0.00		0.00		0.00	
Prob decl>20% (2015-2032)		0.00	(0.00; 0.00)	0.00	(0.00; 0.00)	0.00	(0.00; 0.00)	0.00	(0.00; 0.00)

Table 2: Median and 95% PIs for a series of performance statistics under the **RS** and robustness test **C.future.5** (decrease in *K* in the future, reflected by a 20% linear decrease in *K* for both species between 2015 and 2020, and based on the whole RS) for **CMP2a$_{135}$** (5% downward constraint), and for two CMPs with the extra safeguard rule, **CMP5a$_{135}$** and **CMP5b$_{135}$**. Results for no future catches (C=0) are also shown for the robustness test to illustrate the extent of resource recovery that is possible in those circumstances.

		RS			C.future.5 (20% *K* decrease in the future, based on RS)			
MP:		CMP2a$_{135}$	CMP5a$_{135}$	CMP5b$_{135}$	CMP2a$_{135}$	CMP5a$_{135}$	CMP5b$_{135}$	C=0
C_{2014}		**155.3**	**155.3**	**155.3**	**155.3** (155.3; 155.3)	**155.3**	**155.3**	**155.3**
C_{2015}	BS	147.5 (147.5; 150.0)	147.5 (147.5; 150.0)	147.5 (147.5; 150.0)	147.5 (147.5; 150.0)	147.5 (147.5; 150.0)	147.5 (147.5; 150.0)	**0.0** (0.0; 0.0)
C_{2016}	BS	140.1 (140.1; 144.8)	140.1 (140.1; 144.8)	140.1 (140.1; 144.8)	140.1 (140.1; 144.8)	140.1 (140.1; 144.8)	140.1 (140.1; 144.8)	**0.0** (0.0; 0.0)
C_{2017}	BS	133.1 (133.1; 150.0)	133.1 (129.1; 150.0)	133.1 (133.1; 150.0)	133.1 (126.4; 150.0)	133.1 (124.8; 150.0)	133.1 (126.3; 150.0)	**0.0** (0.0; 0.0)
B^{sp}_{2014}/B_{MSY}	para	0.83 (0.63; 1.26)	0.83 (0.63; 1.26)	0.83 (0.63; 1.26)	0.83 (0.63; 1.26)	0.83 (0.63; 1.26)	0.83 (0.63; 1.26)	0.83 (0.63; 1.26)
B^{sp}_{2015}/B_{MSY}	para	0.74 (0.59; 1.09)	0.74 (0.59; 1.09)	0.74 (0.59; 1.09)	0.74 (0.59; 1.09)	0.74 (0.59; 1.09)	0.74 (0.59; 1.09)	0.74 (0.59; 1.09)
B^{sp}_{2016}/B_{MSY}	para	0.68 (0.52; 1.08)	0.68 (0.52; 1.08)	0.68 (0.52; 1.08)	0.68 (0.52; 1.08)	0.68 (0.52; 1.08)	0.68 (0.52; 1.08)	0.97 (0.67; 1.59)
B^{sp}_{2017}/B_{MSY}	para	0.68 (0.50; 1.23)	0.68 (0.50; 1.23)	0.68 (0.50; 1.23)	0.68 (0.50; 1.23)	0.68 (0.50; 1.23)	0.68 (0.50; 1.23)	1.31 (0.80; 2.37)
avC: 2015-2024	BS	**135.0** (119.3; 147.9)	**135.0** (116.0; 147.9)	**135.0** (115.9; 147.9)	**117.6** (102.0; 138.6)	**110.0** (85.5; 137.3)	**108.5** (84.3; 136.7)	**0.0** (0.0; 0.0)
C_{low}: 2015-2034)	BS	116.4 (94.9; 135.4)	116.3 (88.8; 135.4)	116.4 (88.1; 135.4)	58.2 (44.9; 82.2)	40.9 (23.3; 71.0)	39.3 (20.6; 68.4)	0.0 (0.0; 0.0)
AAV: 2015-2034	BS	0.04 (0.02; 0.05)	0.04 (0.02; 0.06)	0.04 (0.02; 0.06)	0.07 (0.05; 0.08)	0.10 (0.07; 0.13)	0.10 (0.07; 0.13)	1.00 (1.00; 1.00)
$B^{sp}_{low}/B^{sp}_{2014}$	para	0.82 (0.53; 1.00)	0.82 (0.54; 1.00)	0.82 (0.54; 1.00)	0.24 (0.08; 0.54)	0.29 (0.10; 0.58)	0.30 (0.10; 0.58)	0.91 (0.73; 1.01)
$B^{sp}_{low}/B^{sp}_{2014}$	cap	1.02 (0.75; 1.10)	1.02 (0.75; 1.10)	1.02 (0.75; 1.10)	0.39 (0.20; 0.62)	0.45 (0.26; 0.67)	0.45 (0.27; 0.67)	0.63 (0.45; 1.09)
$B^{sp}_{low}/B^{sp}_{2007}$	para	1.35 (0.81; 1.66)	1.35 (0.81; 1.66)	1.35 (0.81; 1.66)	0.40 (0.12; 0.88)	0.50 (0.15; 0.95)	0.51 (0.16; 0.95)	1.54 (1.10; 1.69)
$B^{sp}_{low}/B^{sp}_{2007}$	cap	1.68 (1.29; 1.91)	1.68 (1.29; 1.91)	1.68 (1.29; 1.91)	0.66 (0.35; 0.95)	0.75 (0.46; 1.06)	0.76 (0.47; 1.07)	1.04 (0.75; 1.74)
B^{sp}_{2024}/B_{MSY}	para	1.06 (**0.64;** 2.16)	1.07 (**0.64;** 2.20)	1.07 (**0.64;** 2.24)	0.24 (**0.10;** 0.60)	0.28 (0.14; 0.60)	0.29 (0.16; 0.60)	2.27 (**1.56;** 3.18)
90%iles		(**0.66;** 1.96)	(**0.66;** 2.02)	(**0.66;** 2.02)	(**0.11;** 0.53)	(**0.16;** 0.54)	(**0.17;** 0.54)	(**1.63;** 3.06)
80%iles		(**0.71;** 1.79)	(**0.72;** 1.81)	(**0.72;** 1.81)	(**0.14;** 0.45)	(**0.19;** 0.46)	(**0.20;** 0.46)	(**1.75;** 2.90)
B^{sp}_{2024}/B_{MSY}	cap	3.41 (1.75; 5.07)	3.41 (1.76; 5.08)	3.41 (1.76; 5.07)	1.36 (0.55; 2.01)	1.50 (0.69; 2.23)	1.50 (0.70; 2.24)	2.55 (1.32; 4.35)
B^{sp}_{2034}/B_{MSY}	para	1.15 (0.66; 2.31)	1.15 (0.66; 2.28)	1.15 (0.66; 2.29)	1.06 (0.24; 2.81)	1.58 (0.85; 3.84)	1.66 (0.88; 4.03)	3.65 (1.67; 6.00)
$CPUE_{2024}/CPUE_{2013}$	BS	1.11 (0.90; 1.40)	1.11 (0.90; 1.40)	1.11 (0.90; 1.40)	0.40 (0.27; 0.58)	0.45 (0.30; 0.60)	0.46 (0.31; 0.61)	1.00 (0.64; 1.36)
E_{2024}/E_{2013}	BS	0.78 (0.60; 1.02)	0.78 (0.58; 1.02)	0.78 (0.58; 1.02)	1.32 (0.96; 2.16)	0.79 (0.40; 1.59)	0.67 (0.33; 1.57)	0.00 (0.00; 0.00)
Prob decl >20% (2015-2017)		0.00	0.01	0.01	0.00	0.02	0.01	1.00 (0.00; 0.00)
Prob decl >20% (2016-2018)		0.00	0.03	0.03	0.16	0.18	0.17	0.00 (0.00; 0.00)
Prob decl>20% (2015-2032)		0.00 (0.00; 0.00)	0.00 (0.00; 0.06)	0.00 (0.00; 0.11)	0.00 (0.00; 0.17)	0.22 (0.06; 0.39)	0.22 (0.11; 0.39)	0.00 (0.00; 0.00)

Table 3: Median and 95% PIs for a series of performance statistics under the **RS** for **CMP5a$_{135}$** , and for **CMP6a$_{BR5}$** (with fixed 2015 and 2016 TACs and tuned to the Base Risk (lower 5%ile)).

MP:		Metarule: I^{thres1}=0.8, I^{thres2}=0.6, maxdown=0.80 CMP5a$_{135}$		Metarule as CMP5a135, fixed 2015 and 2016 catches Tuned to Base Risk 5%ile CMP6a$_{BR5}$	
C_{2014}		**155.3**		**155.3**	
C_{2015}	BS	147.5	(147.5; 150.0)	**147.5**	
C_{2016}	BS	140.1	(140.1; 144.8)	**147.5**	
C_{2017}	BS	133.1	(129.1; 150.0)	140.1	(136.0; 144.2)
B^{sp}_{2014}/B_{MSY}	para	0.83	(0.63; 1.26)	0.83	(0.63; 1.26)
B^{sp}_{2015}/B_{MSY}	para	0.74	(0.59; 1.09)	0.74	(0.59; 1.09)
B^{sp}_{2016}/B_{MSY}	para	0.68	(0.52; 1.08)	0.68	(0.52; 1.08)
B^{sp}_{2017}/B_{MSY}	para	0.68	(0.50; 1.23)	0.66	(0.49; 1.21)
avC: 2015-2024	BS	**135.0**	(116.0; 147.9)	**132.1**	(116.0; 146.8)
C_{low}: 2015-2034)	BS	116.3	(88.8; 135.4)	112.4	(85.0; 133.1)
AAV: 2015-2034	BS	0.04	(0.02; 0.06)	0.04	(0.02; 0.07)
$B^{sp}_{low}/B^{sp}_{2014}$	para	0.82	(0.54; 1.00)	0.81	(0.50; 1.00)
$B^{sp}_{low}/B^{sp}_{2014}$	cap	1.02	(0.75; 1.10)	1.03	(0.76; 1.10)
$B^{sp}_{low}/B^{sp}_{2007}$	para	1.35	(0.81; 1.66)	1.33	(0.77; 1.66)
$B^{sp}_{low}/B^{sp}_{2007}$	cap	1.68	(1.29; 1.91)	1.69	(1.31; 1.92)
B^{sp}_{2024}/B_{MSY}	para	1.07	(**0.64;** 2.20)	1.11	(0.62; 2.31)
90%iles			(**0.66;** 2.02)		(**0.66;** 2.08)
80%iles			(**0.72;** 1.81)		(0.73; 1.85)
B^{sp}_{2024}/B_{MSY}	cap	3.41	(1.76; 5.08)	3.44	(1.77; 5.07)
$CPUE_{2024}/CPUE_{2013}$	BS	1.11	(0.90; 1.40)	1.13	(0.92; 1.42)
E_{2024}/E_{2013}	BS	0.78	(0.58; 1.02)	0.72	(0.54; 0.96)
Prob decl >20% (2015-2017)		0.01		0.00	
Prob decl >20% (2016-2018)		0.03		0.01	
Prob decl>20% (2015-2032)		0.00	(0.00; 0.06)	0.00	(0.00; 0.11)

Table 4: Median and 95% PIs for a series of performance statistics under the **RS** and robustness tests **C.future.1a** (industry vessel q is 20% higher than research vessel q) and **C.future.1b** (industry vessel q is 40% higher than research vessel q) for **CMP5a$_{135}$** and **CMP5a$_{BR5}$** (CMP5a$_{135}$ tuned to the Base Risk (lower 5%ile)). Note that the final column reflects what is to be expected if the OMP is selected assuming (for precautionary reasons) that the industry vessel has a q that is 20% higher than the research vessel, but there is actually no difference

MP:		CMP5a$_{135}$			CMP5a$_{BR5}$	
OM:		RS	C.future.1a q industry vessel=1.2q research vessel	C.future.1b q industry vessel=1.4q research vessel	C.future.1a q industry vessel=1.2q research vessel	RS
C_{2014}		**155.3**	155.3	155.3	155.3	155.3
C_{2015}	BS	147.5 (147.5; 150.0)	147.5 (147.5; 150.0)	147.5 (147.5; 150.0)	147.5 (147.5; 150.0)	147.5 (147.5; 147.5)
C_{2016}	BS	140.1 (140.1; 144.8)	140.1 (140.1; 150.0)	140.1 (140.1; 150.0)	140.1 (140.1; 145.8)	140.1 (140.1; 140.1)
C_{2017}	BS	133.1 (129.1; 150.0)	133.1 (133.1; 150.0)	144.6 (133.1; 150.0)	133.1 (133.1; 150.0)	133.1 (129.1; 139.1)
B^{sp}_{2014}/B_{MSY}	para	0.83 (0.63; 1.26)	0.83 (0.63; 1.26)	0.83 (0.63; 1.26)	0.83 (0.63; 1.26)	0.83 (0.63; 1.26)
B^{sp}_{2015}/B_{MSY}	para	0.74 (0.59; 1.09)	0.74 (0.59; 1.09)	0.74 (0.59; 1.09)	0.74 (0.59; 1.09)	0.74 (0.59; 1.09)
B^{sp}_{2016}/B_{MSY}	para	0.68 (0.52; 1.08)	0.68 (0.52; 1.08)	0.68 (0.52; 1.08)	0.68 (0.52; 1.08)	0.68 (0.52; 1.08)
B^{sp}_{2017}/B_{MSY}	para	0.68 (0.50; 1.23)	0.68 (0.50; 1.23)	0.67 (0.49; 1.22)	0.68 (0.50; 1.23)	0.68 (0.50; 1.24)
avC: 2015-2024	BS	**135.0** (116.0; 147.9)	140.3 (120.3; 149.7)	145.0 (125.1; 150.0)	134.5 (118.1; 148.0)	128.5 (112.5; 144.5)
C_{low}: 2015-2034)	BS	116.3 (88.8; 135.4)	121.5 (93.8; 142.5)	127.1 (98.1; 147.5)	114.1 (90.2; 134.8)	109.4 (86.0; 128.3)
AAV: 2015-2034	BS	0.04 (0.02; 0.06)	0.03 (0.01; 0.05)	0.03 (0.00; 0.05)	0.04 (0.02; 0.06)	0.05 (0.02; 0.07)
$B^{sp}_{low}/B^{sp}_{2014}$	para	0.82 (0.54; 1.00)	0.79 (0.53; 1.00)	0.75 (0.48; 0.99)	0.82 (0.53; 1.00)	0.82 (0.54; 1.00)
$B^{sp}_{low}/B^{sp}_{2014}$	cap	1.02 (0.75; 1.10)	1.01 (0.73; 1.10)	0.99 (0.71; 1.10)	1.02 (0.75; 1.10)	1.03 (0.76; 1.10)
$B^{sp}_{low}/B^{sp}_{2007}$	para	1.35 (0.81; 1.66)	1.31 (0.81; 1.65)	1.25 (0.77; 1.63)	1.35 (0.81; 1.66)	1.36 (0.81; 1.67)
$B^{sp}_{low}/B^{sp}_{2007}$	cap	1.68 (1.29; 1.91)	1.65 (1.28; 1.90)	1.63 (1.27; 1.89)	1.68 (1.30; 1.92)	1.69 (1.31; 1.92)
B^{sp}_{2024}/B_{MSY}	para	1.07 (0.64; 2.20)	0.96 (0.53; 2.01)	0.87 (0.44; 1.87)	1.08 (0.64; 2.21)	1.20 (0.69; 2.47)
90%iles		(**0.66;** 2.02)	(0.57; 1.83)	(0.49; 1.70)	(**0.66;** 1.99)	(0.73; 2.21)
80%iles		(0.72; 1.81)	(0.64; 1.65)	(0.56; 1.52)	(0.72; 1.83)	(0.80; 1.98)
B^{sp}_{2024}/B_{MSY}	cap	3.41 (1.76; 5.08)	3.33 (1.70; 4.96)	3.26 (1.65; 4.92)	3.41 (1.76; 5.08)	3.50 (1.81; 5.12)
$CPUE_{2024}/CPUE_{2013}$	BS	1.11 (0.90; 1.40)	1.07 (0.86; 1.36)	1.04 (0.83; 1.33)	1.12 (0.90; 1.41)	1.16 (0.94; 1.44)
E_{2024}/E_{2013}	BS	0.78 (0.58; 1.02)	0.84 (0.65; 1.07)	0.88 (0.68; 1.11)	0.78 (0.57; 1.01)	0.71 (0.52; 0.94)
Prob decl >20% (2015-2017)		0.01	0.00	0.00	0.00	0.01
Prob decl >20% (2016-2018)		0.03	0.01	0.00	0.01	0.02
Prob decl>20% (2015-2032)		0.00 (0.00; 0.06)	0.00 (0.00; 0.00)	0.00 (0.00; 0.00)	0.00 (0.00; 0.00)	0.00 (0.00; 0.11)

Table 5: Median and 95% PIs for a series of performance statistics under the **RS** and robustness tests **C.future.3** (2% p.a. undetected increase in CPUE) and **C.future.3+C.future.1a** (increase in CPUE and industry vessel *q* is 20% higher than research vessel *q*) for **CMP5a$_{135}$**.

MP:		CMP5a$_{135}$					
OM:		RS		C.future.3 2% p.a. undetected increase in CPUE		C.future.3+C.future.1a 2% p.a. undetected increase in CPUE + q industry vessel=1.2q research vessel	
C_{2014}		**155.3**		155.3		155.3	
C_{2015}	BS	147.5	(147.5; 150.0)	147.5	(147.5; 150.0)	147.5	(147.5; 150.0)
C_{2016}	BS	140.1	(140.1; 144.8)	140.1	(140.1; 145.3)	140.1	(140.1; 150.0)
C_{2017}	BS	133.1	(129.1; 150.0)	133.1	(130.1; 150.0)	133.9	(133.1; 150.0)
B^{sp}_{2014}/B_{MSY}	para	0.83	(0.63; 1.26)	0.83	(0.63; 1.26)	0.83	(0.63; 1.26)
B^{sp}_{2015}/B_{MSY}	para	0.74	(0.59; 1.09)	0.74	(0.59; 1.09)	0.74	(0.59; 1.09)
B^{sp}_{2016}/B_{MSY}	para	0.68	(0.52; 1.08)	0.68	(0.52; 1.08)	0.68	(0.52; 1.08)
B^{sp}_{2017}/B_{MSY}	para	0.68	(0.50; 1.23)	0.68	(0.50; 1.23)	0.68	(0.50; 1.23)
avC: 2015-2024	BS	**135.0**	(116.0; 147.9)	138.3	(119.2; 148.8)	142.9	(123.1; 149.9)
C_{low}: 2015-2034)	BS	116.3	(88.8; 135.4)	120.5	(96.6; 140.1)	126.5	(101.8; 145.8)
AAV: 2015-2034	BS	0.04	(0.02; 0.06)	0.03	(0.01; 0.05)	0.03	(0.00; 0.05)
$B^{sp}_{low}/B^{sp}_{2014}$	para	0.82	(0.54; 1.00)	0.79	(0.53; 1.00)	0.77	(0.49; 0.99)
$B^{sp}_{low}/B^{sp}_{2014}$	cap	1.02	(0.75; 1.10)	1.00	(0.73; 1.10)	0.99	(0.71; 1.10)
$B^{sp}_{low}/B^{sp}_{2007}$	para	1.35	(0.81; 1.66)	1.32	(0.81; 1.65)	1.27	(0.77; 1.63)
$B^{sp}_{low}/B^{sp}_{2007}$	cap	1.68	(1.29; 1.91)	1.65	(1.27; 1.90)	1.63	(1.26; 1.89)
B^{sp}_{2024}/B_{MSY}	para	1.07	(0.64; 2.20)	1.01	(0.59; 2.12)	0.92	(0.50; 1.96)
90%iles			(**0.66;** 2.02)		(0.63; 1.89)		(0.54; 1.77)
80%iles			(0.72; 1.81)		(0.68; 1.73)		(0.61; 1.58)
B^{sp}_{2024}/B_{MSY}	cap	3.41	(1.76; 5.08)	3.38	(1.73; 5.03)	3.30	(1.67; 4.94)
$CPUE_{2024}/CPUE_{2013}$	BS	1.11	(0.90; 1.40)	1.09	(0.88; 1.38)	1.06	(0.84; 1.34)
E_{2024}/E_{2013}	BS	0.78	(0.58; 1.02)	0.83	(0.64; 1.05)	0.87	(0.68; 1.10)
Prob decl >20% (2015-2017)		0.01		0.01		0.00	
Prob decl >20% (2016-2018)		0.03		0.02		0.01	
Prob decl>20% (2015-2032)		0.00	(0.00; 0.06)	0.00	(0.00; 0.00)	0.00	(0.00; 0.00)

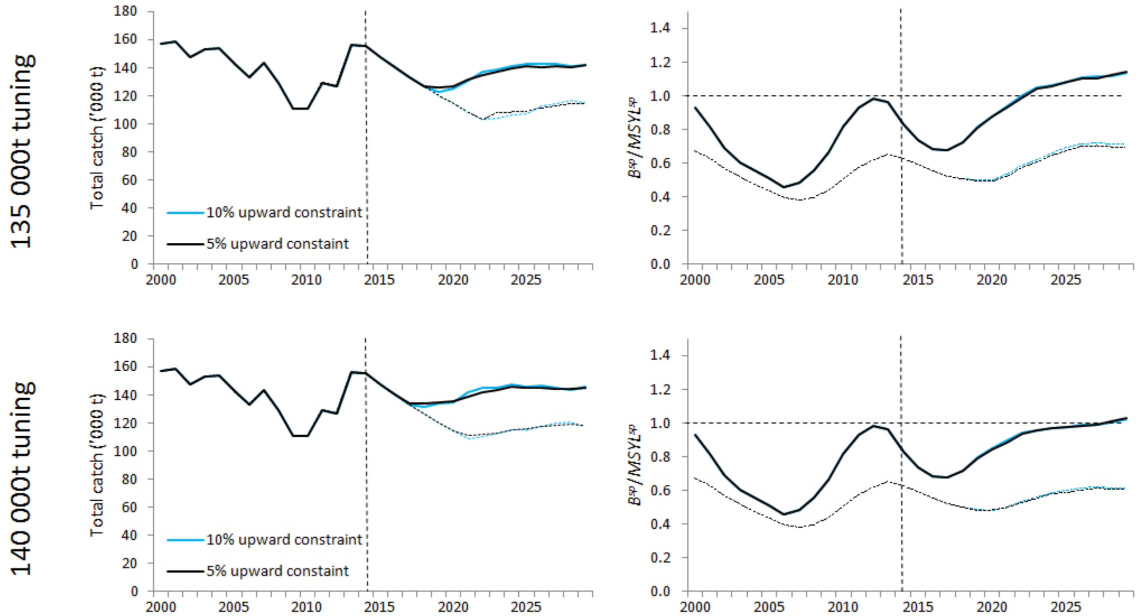

Figure 1: Medians (full lines) and lower 5%iles (top row (dotted lines) for total catch (LHS) and *M. paradoxus* spawning biomass (relative to MSYL level - RHS) for the RS under **CMP2a$_{135}$ (10% upward constraint)** and **CMP4a$_{135}$ (5% upward constraint)** and under **CMP2a$_{140}$ (10% upward constraint)** and **CMP4a$_{140}$ (5% upward constraint)**.

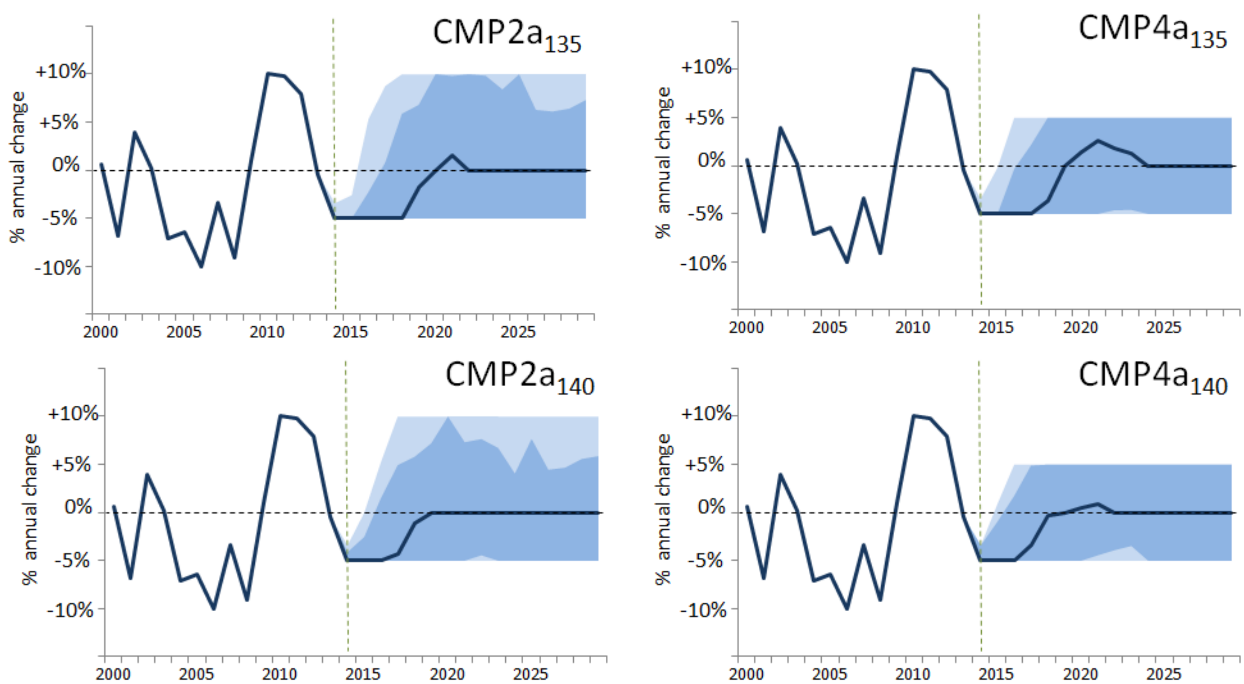

Figure 2: 95% and 75% PI envelopes and medians of percentage annual change in TAC for the RS under **CMP2a$_{135}$, CMP2a$_{140}$, CMP4a$_{135}$** and **CMP4a$_{140}$**.

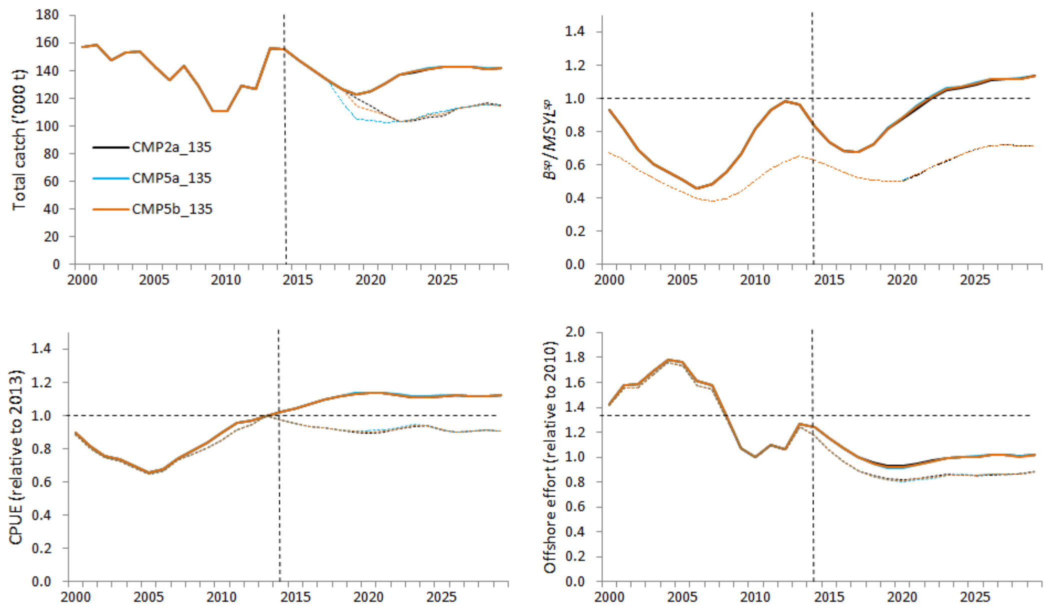

Figure 3: Medians (full lines) and lower **5%iles** (dotted lines) for total catch (top row, LHS), *M. paradoxus* spawning biomass (relative to MSYL level - top row, RHS), CPUE (relative to 2013, bottom row, LHS) and effort (relative to 2010, bottom row, RHS) for the **RS** under **CMP2a$_{135}$** and two CMPs with the extra safeguard rule: **CMP5a$_{135}$** and **CMP5b$_{135}$**.

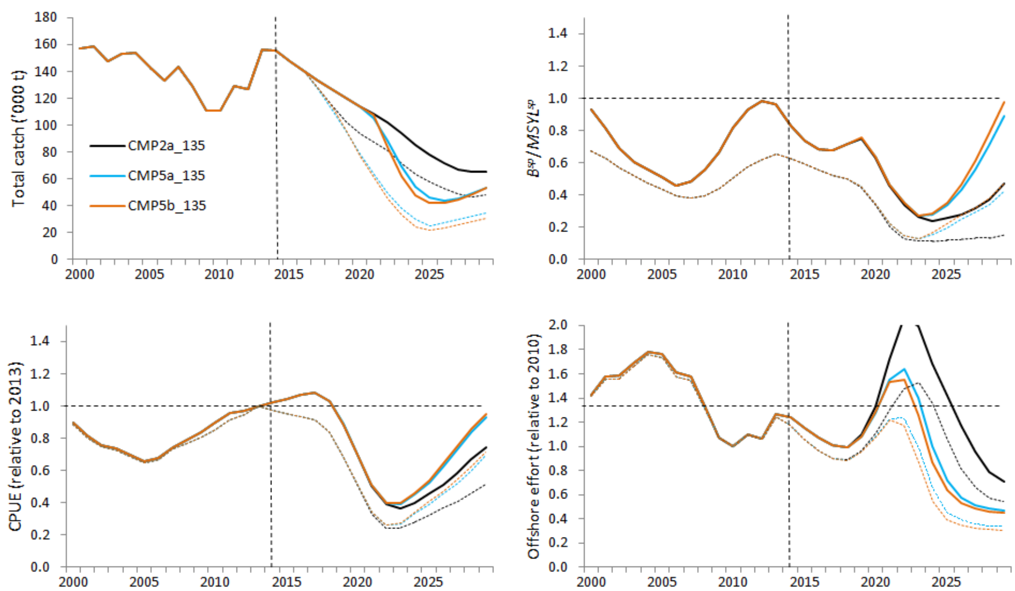

Figure 4: Medians (full lines) and lower **5%iles** (dotted lines) for total catch (top row, LHS), *M. paradoxus* spawning biomass (relative to MSYL level - top row, RHS), CPUE (relative to 2013, bottom row, LHS) and effort (relative to 2010, bottom row, RHS) for **the robustness test C.future.5** (decrease in *K* in the future, reflected by a 20% linear decrease in *K* for both species between 2015 and 2020, and based on the whole RS) under **CMP2a$_{135}$** and two CMPs with the extra safeguard rule: **CMP5a$_{135}$** and **CMP5b$_{135}$**.

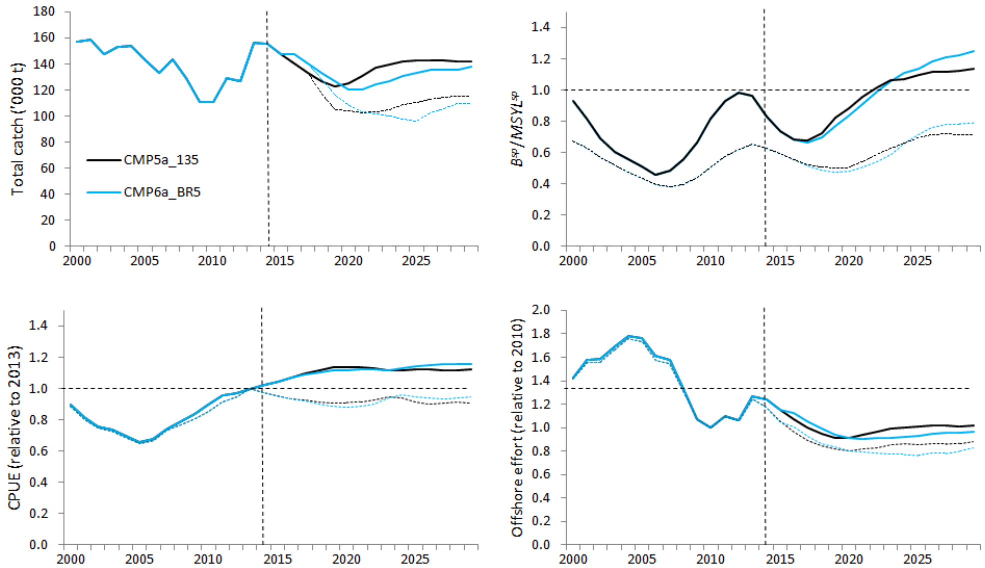

Figure 5: Medians (full lines) and lower **5%iles** (dotted lines) for total catch (top row, LHS), *M. paradoxus* spawning biomass (relative to MSYL level - top row, RHS), CPUE (relative to 2013, bottom row, LHS) and effort (relative to 2010, bottom row, RHS) for **RS** under **CMP5a$_{135}$** and **CMP6a$_{BR5}$** (with fixed 2015 and 2016 TACs and the safeguard rule as for CMP5a135, tuned to 5% Base Risk).

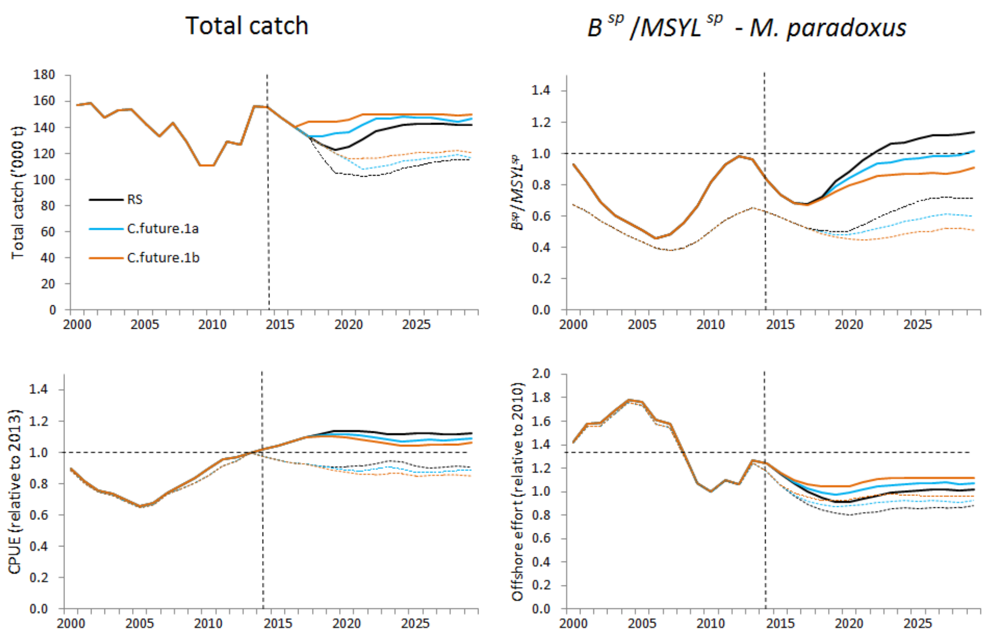

Figure 6a: Medians (full lines) and lower **5%iles** (dotted lines) for total catch (top row, LHS), *M. paradoxus* spawning biomass (relative to MSYL level - top row, RHS), CPUE (relative to 2013, bottom row, LHS) and effort (relative to 2010, bottom row, RHS) under the **RS** and robustness tests **C.future.1a** (industry vessel *q* is 20% higher than research vessel *q*) and **C.future.1b** (industry vessel *q* is 40% higher than research vessel *q*) for **CMP5a$_{135}$**.

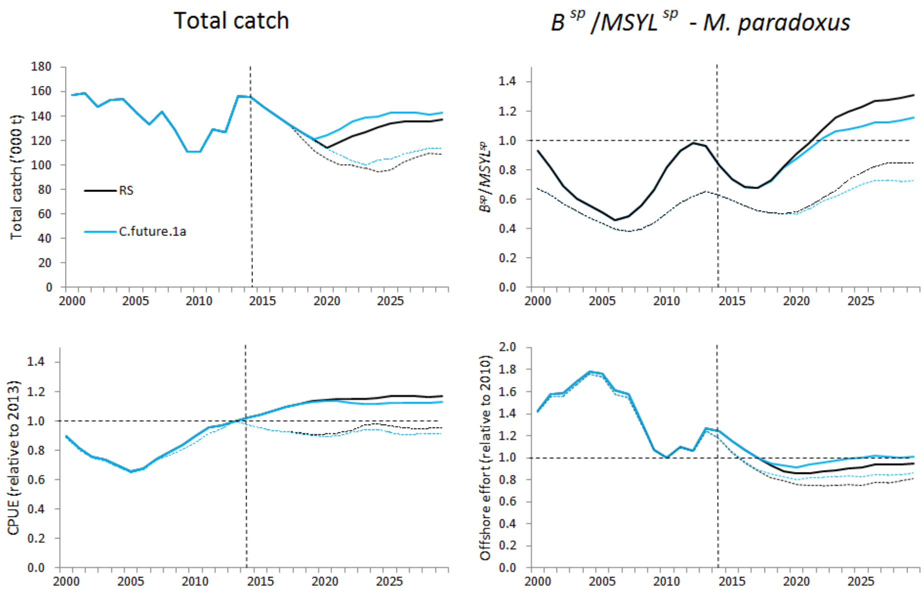

Figure 6b: Medians (full lines) and lower **5%iles** (dotted lines) for total catch (top row, LHS), *M. paradoxus* spawning biomass (relative to MSYL level - top row, RHS), CPUE (relative to 2013, bottom row, LHS) and effort (relative to 2010, bottom row, RHS) under the robustness test **C.future.1a** (industry vessel *q* is 20% higher than research vessel *q*) for **CMP5a**$_{\mathbf{BR5}}$ (CMP5a135 tuned to the Base Risk (lower 5%ile) under C.future.1a). Here the results shown under RS reflect the situation where **CMP5a**$_{\mathbf{BR5}}$ has been implemented for precautionary reasons, but the industry vessel actually has the same *q* as the research vessel.

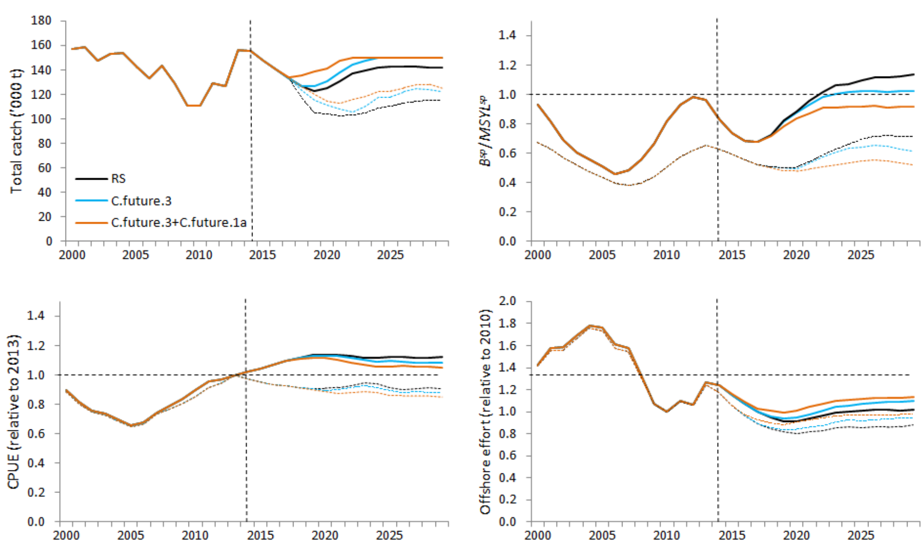

Figure 7: Medians (full lines) and lower **5%iles** (dotted lines) for total catch (top row, LHS), *M. paradoxus* spawning biomass (relative to MSYL level - top row, RHS), CPUE (relative to 2013, bottom row, LHS) and effort (relative to 2010, bottom row, RHS) under the **RS** and robustness tests **C.future.3** (2% p.a. undetected increase in CPUE) and **C.future.3+C.future.1a** (in addition the industry vessel has a 20% higher *q* than the research vessel) for **CMP5a**$_{\mathbf{135}}$.