

## Updated Reference Set Operating Model results for South African hake

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Results are given in Table 1 for a full cross of 3 centre-years x 3 natural mortality vectors x 2 stock-recruitment relationships (two OM's are still being run) that cover the key hake assessment uncertainties included in the Reference Set, which is now updated (both in terms of changes in methodology and further years data) to 2017. Specifically the values for these uncertainty factors are:

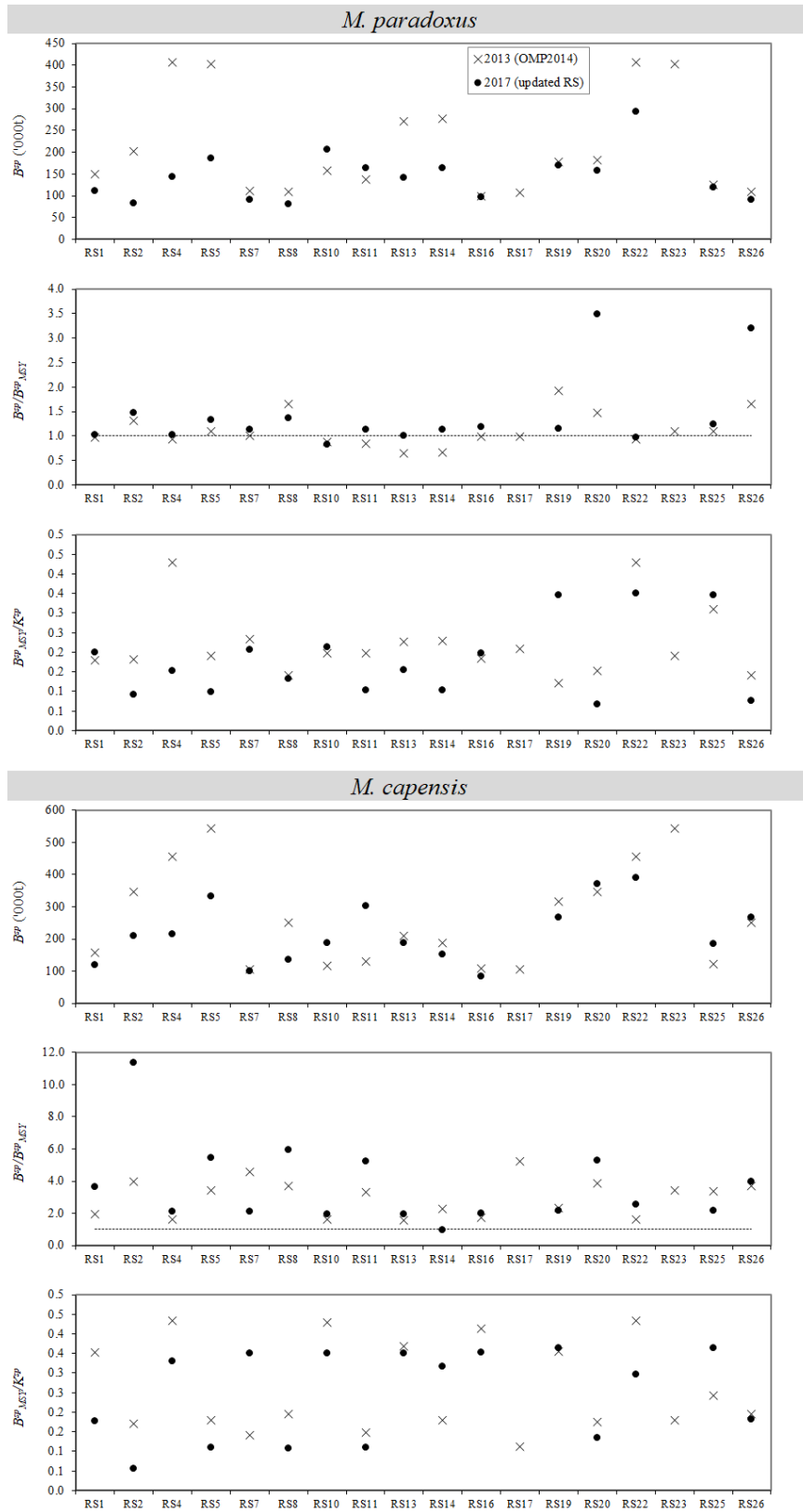
- Centre years for change from *M. capensis* to *M. paradoxus* dominance in catch: 1950, 1958 and 1965.
- Natural mortality vectors: "Mmed":  $M_2=0.75$  and  $M_{5+}=0.375$ , "Mlow":  $M_2=0.6$  and  $M_{5+}=0.25$  and "Mhigh":  $M_2=0.9$  and  $M_{5+}=0.5$ .
- Stock-recruitment relations: "Ricker": modified Ricker and "BH": Beverton-Holt,  $h$  estimated

Figure 1 compares the current (2017) spawning biomass (in absolute terms and relative to  $B_{MSY}$ ) and  $B_{MSY}/K$  across the range of OM's, as well as the difference in the total negative log-likelihood ( $\Delta\text{-lnL}$ ) from the best fitting OM. These are also compared to the equivalent estimates (2013 instead of 2017) used for developing the 2014 OMP. The corresponding updated spawning biomass trajectories plotted in Figures 2. Figure 3 plots the median and range (minimum and maximum) spawning biomass trajectories for the updated RS.

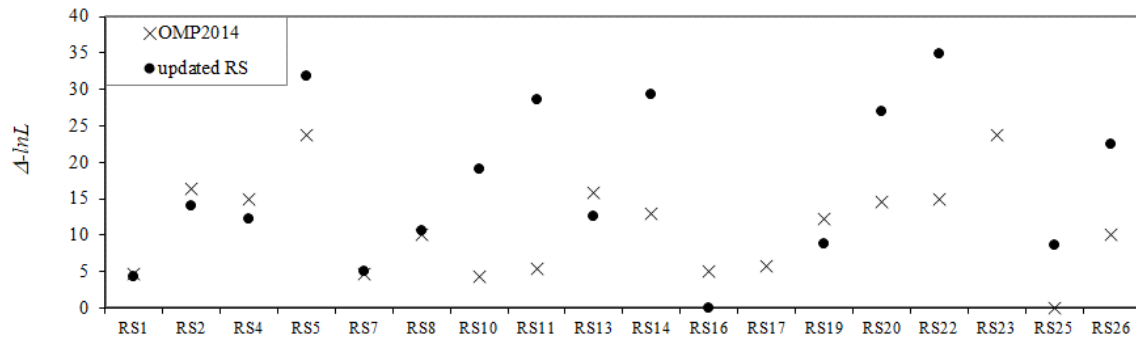
While  $B_{MSY}/K$  spans a wide range for *M. paradoxus* and particularly for *M. capensis*, for the former at least  $B_{2017}/B_{MSY}$  does now seem reasonably robustly estimated across the OM's (though with two exceptions). For the most part, patterns in  $\Delta\text{-lnL}$  across the OM's are maintained, though tending to be larger as to be expected given more data. Cases where  $\Delta\text{-lnL}$  increases appreciably are for RS14, RS22 and RS26 (all members of the previous final RS), and RS10, RS11 and RS20,

**Table 1:** Results for the updated RS. As the OM notation does not correspond to that used in document Hake/P9, the latter's notation has been included in the Table. The OMs that have a "Hake/P9 notation" were included in the final RS used in the development of OMP2014.

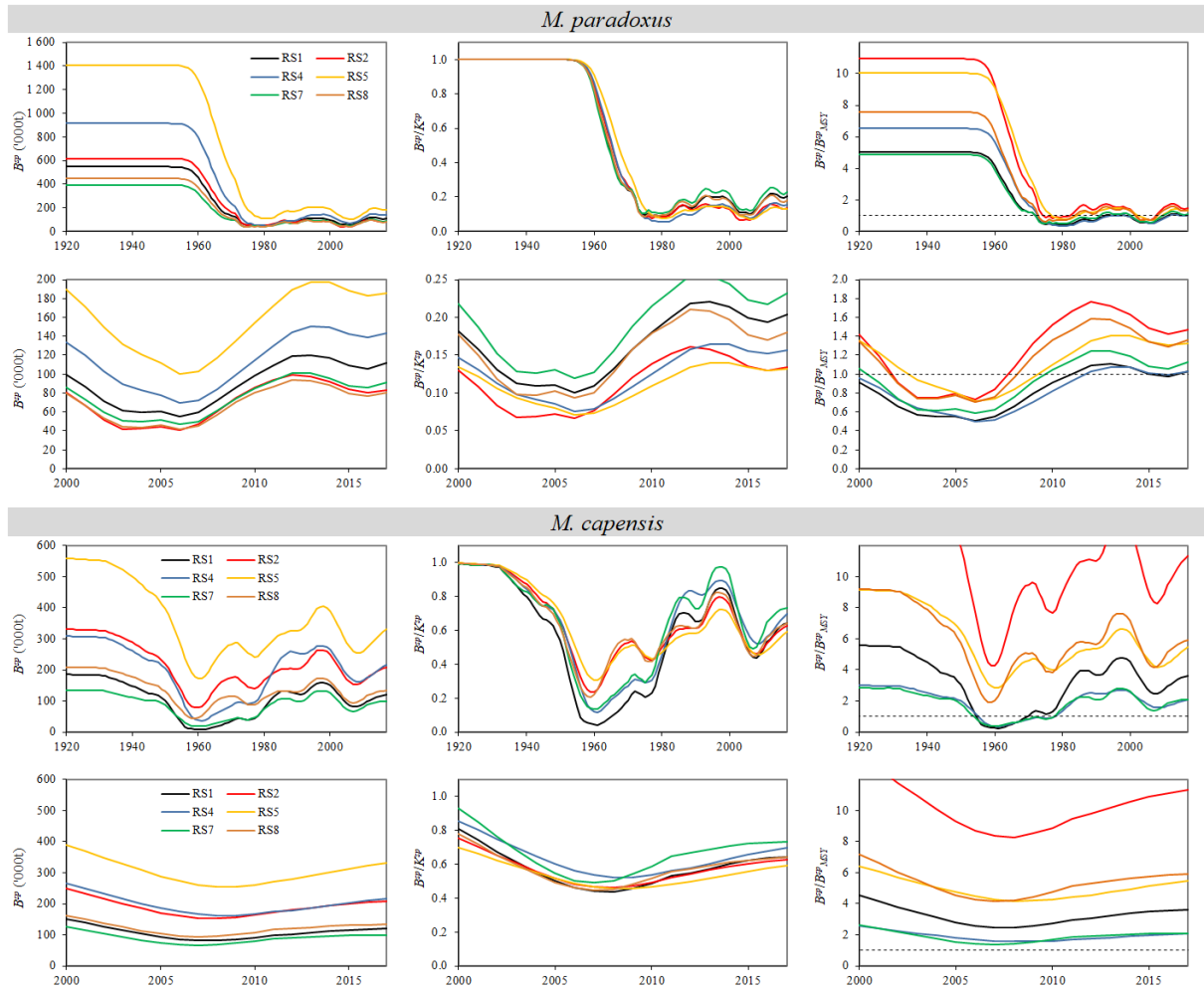
Doc P9 notation	RS1	RS2							RS4	RS5	RS7				RS10		RS13	RS14
	RS1	RS2	RS4	RS5	RS7	RS8	RS10	RS11	RS13	RS14	RS16	RS17	RS19	RS20	RS22	RS23	RS25	RS26
	1958	1958	1958	1958	1958	1958	1950	1950	1950	1950	1950	1950	1965	1965	1965	1965	1965	1965
	Mmed	Mmed	Mlow	Mlow	Mhigh	Mhigh	Mmed	Mmed	Mlow	Mlow	Mhigh	Mhigh	Mmed	Mmed	Mlow	Mlow	Mhigh	Mhigh
	Ricker	BH	Ricker	BH	Ricker	BH	Ricker	BH	Ricker	BH	Ricker	BH	Ricker	BH	Ricker	BH	Ricker	BH
$\Delta$ -lnL during OMP2014 testing	4.7	16.3	14.9	23.6	4.6	10.1	4.3	5.4	15.8	13.0	5.0	5.8	12.1	14.6	14.9	23.6	0.0	10.1
-lnL total	-5244.1	-5234.3	-5236.2	-5216.6	-5243.3	-5237.8	-5229.3	-5219.7	-5235.8	-5219.0	-5248.3		-5239.6	-5221.3	-5213.5		-5239.7	-5225.8
$\Delta$ -lnL	4.3	14.1	12.1	31.8	5.0	10.6	19.1	28.6	12.6	29.4	0.0		8.7	27.0	34.8		8.7	22.5
<i>M. paradoxus</i>																		
$K^{sp}$	547	618	914	1406	394	448	1173	1393	915	1393	414		429	670	870		280	371
$B^{sp}_{MSY}$	109	56	140	140	81	59	250	144	142	144	82		149	45	304		97	28
$B^{sp}_{MSY}/K^{sp}$	0.20	0.09	0.15	0.10	0.21	0.13	0.21	0.10	0.15	0.10	0.20		0.35	0.07	0.35		0.34	0.08
$B^{sp}_{2017}$	112	83	143	185	91	81	205	163	142	163	97		171	158	294		120	91
$B^{sp}_{2017}/K^{sp}$	0.20	0.13	0.16	0.13	0.23	0.18	0.18	0.12	0.15	0.12	0.23		0.40	0.24	0.34		0.43	0.25
$B^{sp}_{2017}/B^{sp}_{MSY}$	1.03	1.47	1.02	1.32	1.13	1.36	0.82	1.14	1.00	1.13	1.19		1.15	3.49	0.96		1.24	3.20
$MSY$	141	141	150	146	142	141	149	146	150	146	139		139	144	148		140	155
<i>M. capensis</i>																		
$K^{sp}$	187	332	310	560	136	210	273	528	273	487	119		339	521	520		234	371
$B^{sp}_{MSY}$	33	18	103	61	48	23	96	58	96	154	42		124	70	154		85	67
$B^{sp}_{MSY}/K^{sp}$	0.18	0.06	0.33	0.11	0.35	0.11	0.35	0.11	0.35	0.32	0.35		0.36	0.13	0.30		0.36	0.18
$B^{sp}_{2017}$	120	209	216	332	100	134	187	304	188	151	83		267	372	391		184	268
$B^{sp}_{2017}/K^{sp}$	0.64	0.63	0.70	0.59	0.73	0.64	0.69	0.58	0.69	0.31	0.70		0.79	0.71	0.75		0.78	0.72
$B^{sp}_{2017}/B^{sp}_{MSY}$	3.62	11.33	2.10	5.45	2.09	5.92	1.96	5.25	1.96	0.98	1.98		2.16	5.30	2.54		2.15	3.98
$MSY$	79	93	71	74	84	111	65	70	65	39	72		117	127	108		123	136



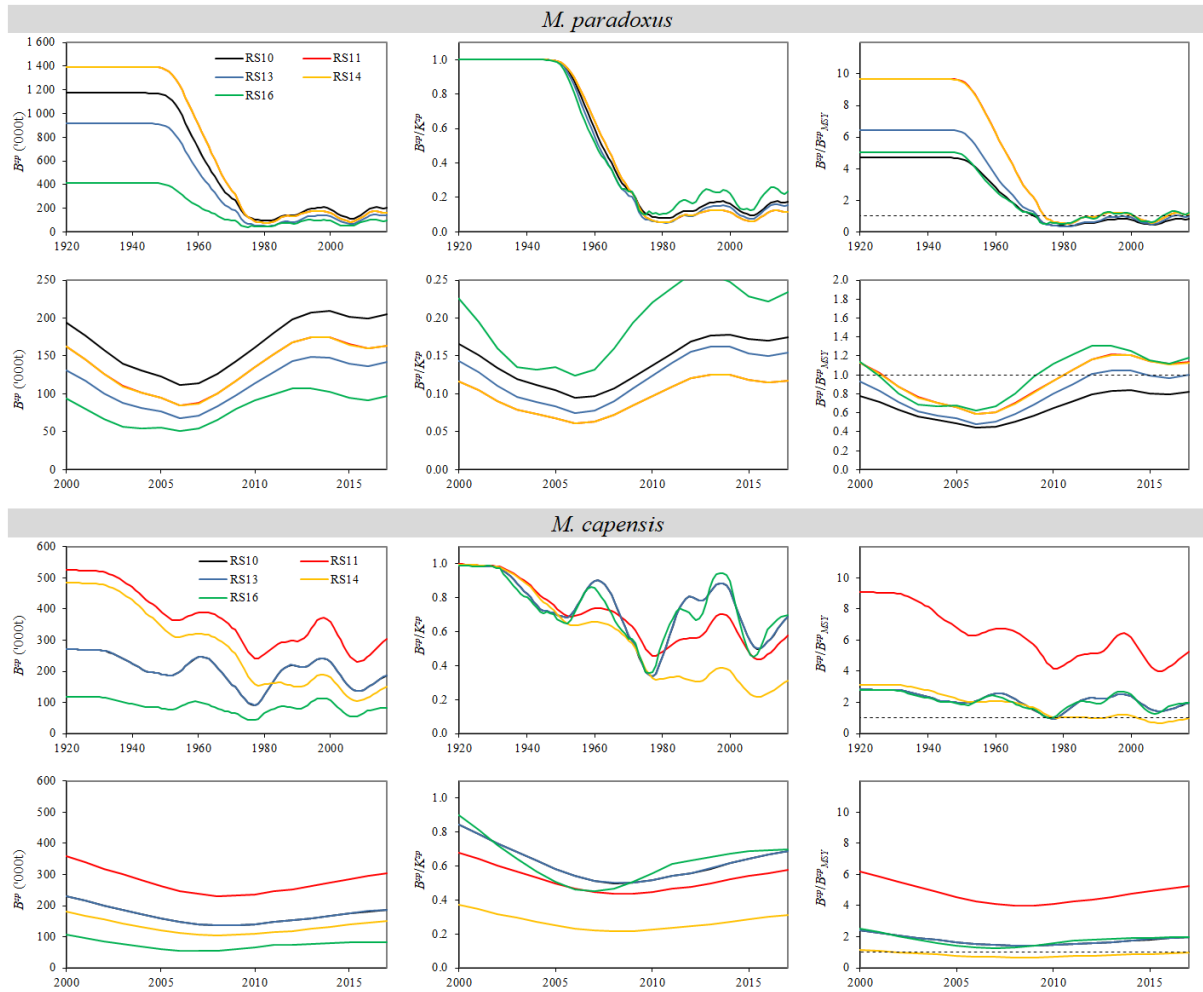
**Figure 1a:** Current (2017, updated RS) and 2013 (used for OMP2014 development) spawning biomass (in absolute terms and relative to  $B_{MSY}$ ), and  $B_{MSY}/K$  across the range of OM.



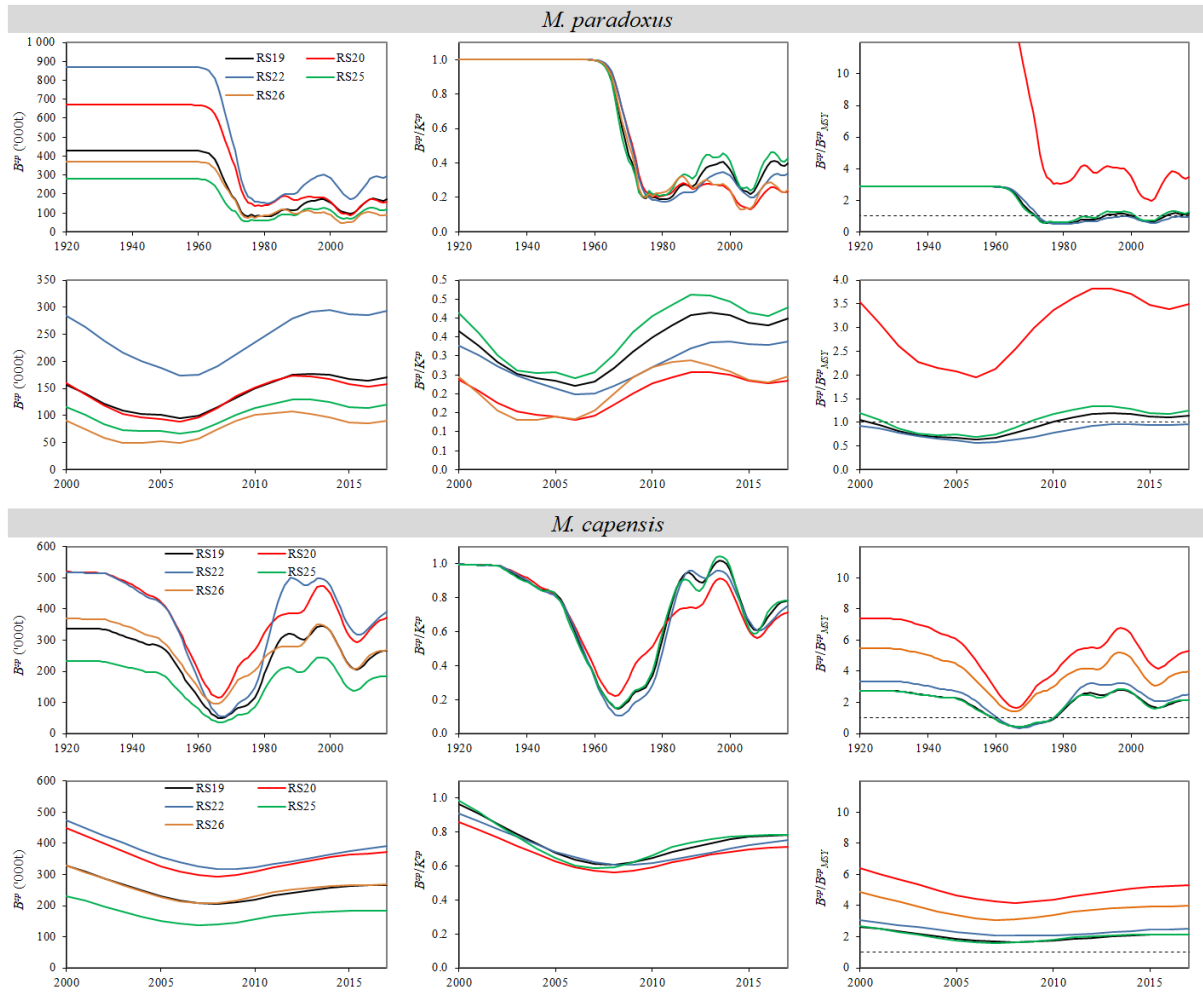
**Figure 1b:**  $\Delta \ln L$  for the updated RS and for these OMs at the time OMP2014 was developed.



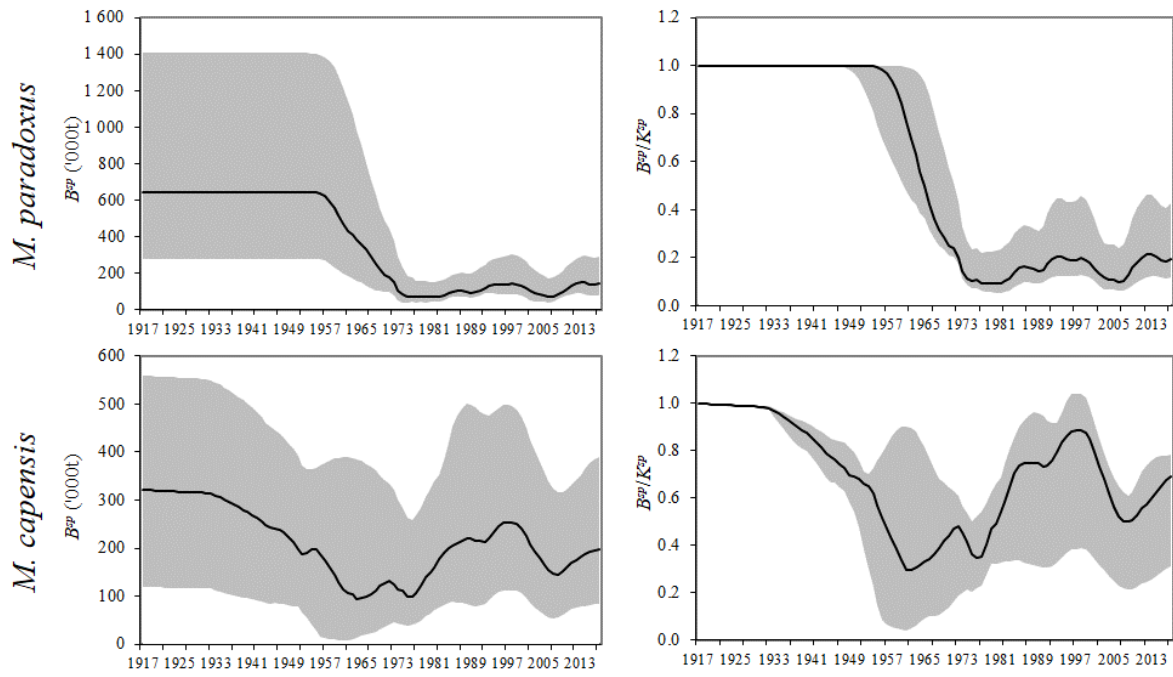
**Figure 2a:** Female spawning biomass trajectories (in absolute terms - first column -, relative to pre-exploitation level - second column - and relative to  $B_{MSY}$  - third column) for *M. paradoxus* and *M. capensis* for OM with 1958 as the mid-change year. The second and fourth rows are the same as the first and third respectively, except for the horizontal axis covering only more recent years.



**Figure 2b:** Female spawning biomass trajectories (in absolute terms - first column -, relative to pre-exploitation level - second column - and relative to  $B_{MSY}$  - third column) for *M. paradoxus* and *M. capensis* for OMs with **1950** as the mid-change year. The second and fourth rows are the same as the first and third respectively, except for the horizontal axis covering only more recent years.



**Figure 2c:** Female spawning biomass trajectories (in absolute terms - first column -, relative to pre-exploitation level - second column - and relative to  $B_{MSY}$  - third column) for *M. paradoxus* and *M. capensis* for OMs with 1965 as the mid-change year. The second and fourth rows are the same as the first and third respectively, except for the horizontal axis covering only more recent years.



**Figure 3:** Median (black line) with minimum-maximum range (shading) spawning biomass trajectories (in absolute terms and relative to pre-exploitation level) for *M. paradoxus* and *M. capensis*, for the updated RS.