List of Suggested Robustness Tests for the Revised Hake OMP

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A list of suggested robustness tests for use in OMP testing is given below. The robustness tests that were found to present the greatest challenges from a resource conservation perspective during the development of OMP-2011 (see Appendix A) are shaded below.

A. Data input options

Catches

A.catches.1: Offshore trawl (post-1978): Alternative species split of the offshore trawl catches from a species-splitting algorithm obtained from an analysis of observer data.

A.catches.2: As A.catches.1 above, used in conjunction with alternative GLM-standardised CPUE based on observer data.

A.catches.3: Including discards. Discarding by offshore and inshore trawlers is modelled as an increase in the commercial selectivity of 0.2 for ages 1 and 2 for *M. capensis* and *M. paradoxus*; the loss of fish from longlines is also included by doubling *F* from this fleet.

A.catches.4: Alternative inshore trawl catch species split (assume 20% *M. paradoxus*).

CPUE

A.CPUE.1: Changes in efficiency the CPUE series because of the introduction of navigational aides; split series in 1994/1995, with different *q*'s estimated for the two periods.

A.CPUE.2: From 1997 to 2002 *q* for CPUE dropped by 20% as a result of shorter tows.

A.CPUE.3: Fit in addition to longline CPUE series.

A.CPUE.4: Added weighting on the last five years' CPUE and survey data to fit recent abundance indices more closely.

Surveys

A.survey.1: Alternative calibration factors between old and new *Africana* gear.

A.survey.2: Adjust survey abundance estimates to take account of environmental co-variates.

A.survey.3: Include 2013 *Nansen* calibrated abundance estimates with some allowance for correlation with *Africana* survey results.

Age and length data

A.length.1: Ageing out by 1 year for *M. capensis* and *M. paradoxus.*

A.length.2: Ages of *M. capensis* halved.

B. Model assumptions

Selectivities

B.sel.1: Alternative slope assumptions (all commercial and survey selectivity slopes (in cm^{-1}): +0.04, b)+0.02, c)-0.04 and d) -0.02).

B.sel.2: Alternative assumption re *M. capensis* offshore selectivity (RC: as inshore, shifted 10cm with slope of 1/3 of inshore slope).

B.sel.3: Alternative assumption re south coast female *M. paradoxus* selectivity scaling factor.

B.sel.4: Allow random walk variation over time in selectivities-at-length.

B.sel.5: SAM-based assessment.

Natural Mortality

B.M.1: Gender-specific natural mortality (+0.05 for males, -0.05 for females).

B.M.2: Increasing *M* at large ages (linear from 0.375 at age 8 to 1 at age 15)

Stock-recruitment relationship

B.SR.1: Alternative σ_R values. (Model as random effect to estimate directly – convergence permitting.)

B.SR.2: Alternative male/female ratio at birth (instead of 50/50).

B.SR.3: Other combinations of BH/Ricker and level of natural mortality (Rob5 based on RS1 and RS11 of OMP-2011: True Ricker, trawl catches shift center in 1950 and M_{2-}=0.9 and M_{5+}=0.5 for both species).

B.SR.4: No shrinkage of recent recruitments towards the stock-recruitment relationship prediction.

Other model assumptions

B.others.1: Assessments commencing in 1978, estimating q and ζ.

B.others.2: Changes in past *K* values over time (30% linear decrease over 1980 to 2000 for both species).

B.others.3: Alternative weighting for length data (W_{CAL}=0.01 and W_{CAL}=1.0).

B.others.4: Alternative weighting for age-length-key data (W_{ALK}=0.001 and W_{ALK}=0.1).

B.others.5: Estimating somatic growth externally.

B.others.6: Alternative maturity-at-length with fixed lower *h* values.

C. Changes in the future

C.future.1: Missing/reduced surveys and surveys on another only partially calibrated vessel.

C.future.2: Decrease all future survey CVs by a multiplicative factor of 1/SQRT(2).

C.future.3: MPA possible effects on future CPUE: a. no CPUE; b. new CPUE series with prior on *q*; c. new CPUE series with lower *q*; d. new CPUE series with higher *q*; and e. new CPUE series with no prior on *q*.

C.future.2: Trend in Fratio over time. (assumed constant for the RS (Rademeyer and Butterworth, 2010a): a. +2% p.a. and b. -2% p.a., for 10 years, then constant.

C.future.3: Undetected increase in catchability related to CPUE.

C.future.4: Change in discard pattern.

C.future.5: Decrease in *K*.

C.future.6: Allow for serial correlation in recruitment residuals.

C.future.7: Maximum proportion of cohort catchable in one year decreases from 90% to 70%.

REFERENCES

Rademeyer RA and Butterworth DS. 2010a. Candidate Management Procedures for the South African Hake Resource: Draft Objectives and Testing Methodology. Unpublished report. MCM/2010/MAY/SWG-DEM/22(Rev).

Rademeyer RA and Butterworth DS. 2010b. Conditioning of the full set of robustness tests for the South African hake resource to be used in OMP-.2010 testing and constant catch projections. Unpublished report. MCM/2010/JUNE/SWG-DEM/31.

Appendix A: OMP-2011 robustness tests

Results for a set of robustness tests and constant catch projections (150 000t) were presented in Rademeyer and Butterworth (2010b). Based on these results, a subset of robustness tests was selected to test the CMPs routinely, as only the final one or two CMPs were checked on the complete suite of robustness tests. The selection was based on which tests appeared under constant catch projections to present the greatest challenges from a resource conservation perspective.

The complete list of robustness tests is given in Tables App.A.1 and App.A.2. Three performance statistics ($B^{sp}_{2027}/B^{sp}_{MSY}$, B^{sp}_{2030}/K^{sp} and $B^{sp}_{2030}/B^{sp}_{2010}$ for the female component of the population) are plotted in Figs App.A.1 and App.A.2 for the full set of RS and robustness tests under a constant catch of 150 000t.

Tests related to *M. paradoxus*

The following robustness tests related to *M. paradoxus* were retained in the selected set:

Changes in the past:

Rob5 (true Ricker), Rob13 (decrease in *K*), Rob17 (start in 1978) and Rob25 (lower steepness *h*).

Changes in the future:

(Naturally constant catch projections do not provide discrimination amongst tests that involve changes to default assumptions for aspects of future data such as changes in precision, so that all such tests were retained in the selected set.)

Rob31f (case of no surveys and an undetected catchability trend for CPUE), Rob35 (undetected catchability trend for CPUE) and Rob37 (decrease in *K*).

Tests related to *M. capensis*

The robustness tests described in Table App.A.1 are mostly based on RS1, for which *M. capensis* was well above MSYL at that time. Robustness tests were also needed in the case when the extent of *M. capensis* depletion was estimated to be relatively high and four robustness tests were selected to be run on RS11 (Table App.A.2). For changes in the past, three of the four robustness tests selected for *M. paradoxus* testing above were chosen (Rob5, Rob13 and Rob25, but not Rob17 which is of a different nature and does not show *M. capensis* to be heavily depleted) and for changes in the future, Rob37 (decrease in *K*) was selected.

Table App.A.1: Summary of the full set of robustness/sensitivity tests.

	Shift center	SR relationship	Natural mortality		Other
			M. paradoxus	*M. capensis*	
Changes in the past					
Rob1	1965	BH, h estimated	$M_{2.}$=0.6; M_{5+}=0.25	$M_{2.}$=0.9; M_{5+}=0.5	
Rob2	1950	BH, h estimated	$M_{2.}$=0.9; M_{5+}=0.5	$M_{2.}$=0.6; M_{5+}=0.25	
Rob3	1965	BH, h estimated	$M_{2.}$=0.9; M_{5+}=0.5	$M_{2.}$=0.6; M_{5+}=0.25	
Rob4	1950	True Ricker	$M_{2.}$=0.6; M_{5+}=0.25	$M_{2.}$=0.6; M_{5+}=0.25	
Rob5	1950	True Ricker	$M_{2.}$=0.9; M_{5+}=0.5	$M_{2.}$=0.9; M_{5+}=0.5	
Rob6			as RS1		σ_R = 0.25
Rob7			as RS1		W_{ALK} = 0.001
Rob8			as RS1		W_{ALK} = 0.1
Rob9			as RS1		W_{CAL} = 0.01
Rob10			as RS1		W_{CAL} = 1.0
Rob11			as RS1		M gender dependent (+0.05 for males, -0.05 for females)
Rob12			as RS1		All commercial and survey selectivity slopes (in cm^{-1}): a)+0.04, b) +0.02, c) -0.04 and d) -0.02
Rob13			as RS1		Decrease in K (30% linear decrease between 1980 and 2000 for both spp)
Rob14			as RS1		Added weighting (5x) to last 5 year's CPUE and survey data to fit recent abundance indices more closely
Rob15			as RS1		No shrinkage of recent recruitments towards the stock-recruitment relationship prediction
Rob 16			as RS2		Increasing M at large ages (linear from 0.25 at age 8 to 1 at age 15)
Rob17			as RS1		Start in 1978, estimating θ and ζ
Rob 18			as RS1		Change in efficiency in the offshore trawl fleet 1994/1995
Rob 19			as RS1		Different CPUE series: a. all offshore vessels incl.; b. alt. depth stratifications; c. omit days with nominal CPUE=0; (d. updated after database check)
Rob 20			as RS1		Survey calibration factor: a. incr. cap. factor to 0.9; b. decr. cap. factor to 0.6; c. both cap. and para. factors estimated
Rob 21			as RS1		Ageing of both species out by one year
Rob 22			as RS1		Ageing of both species to be halved
Rob 23			as RS1		Alternative assumption for the cap. offshore selectivity
Rob 24			as RS1		Alternative assumption re SC female paradoxus selectivity scaling factor: a. as lower; b. as higher
Rob 25			as RS1		Alternative maturity-at-length with fixed lower h values
Rob 26			as RS1		Include discards in the past
Rob 27			as RS1		40/60 male/female ratio at birth instead of 50/50
Rob 28			as RS1		Alternative species split algorithm (post-1978 catches and CPUE series)
Rob 29			as RS1		From 1997 to 2002 q for CPUE dropped by 20% as a result of shorter tows
Changes in the future					
Rob 30			as RS1		Maximum proportion of cohort catchable in one year decrease from 90% to 70%
Rob 31			as RS1		Missing/reduced surveys in the future: a. no surveys; b. only WC surveys; c. only SC surveys; d. both surveys missing every 3 years; e. increase all future surveys CVs by multiplicative factor of sqrt(2); f. no surveys plus undetected increase catchability related to CPUE
Rob 32			as RS1		Decrease all future survey CVs by a multiplicative factor of 1/sqrt(2)
Rob 33			as RS1		MPA possible effects on future CPUE: a. no CPUE; b. new CPUE series with prior on q; c. new CPUE series with lower q; d. new CPUE series with higher q; and e. new CPUE series with no prior on q
Rob 34			as RS1		Trend in F_{ratio} over time in the future: a) 2% p.a. and b) -2% p.a., for 10 years then constant
Rob 35			as RC		Undetected 2% p.a. increase in catchability related to CPUE in the future
Rob 36			as Rob26		Change in discard pattern in the future: a) past, but no future discards; b) past and future discards; c) past discards are halved in the future.
Rob 37			as RS1		Decrease in K in the future (30% linear decrease between 2011 and 2016 for both spp)
Rob 38			as RS1		Allow for serial correlation in recruitment residuals (estimate from RC fit)

Table App.A.2: Summary of the set of robustness/sensitivity tests related particularly to *M. capensis*.

	Shift center	SR relationship	Natural mortality		Other
			M. paradoxus	*M. capensis*	
Changes in the past					
Rob5	1950	True Ricker	$M_{2\text{-}}$=0.9; M_{5+}=0.5	$M_{2\text{-}}$=0.9; M_{5+}=0.5	
Rob6			as RS11		σ_R = 0.25
Rob13			as RS11		Decrease in K (30% linear decrease between 1980 and 2000 for both spp)
Rob17			as RS11		Start in 1978, estimating θ and ζ
Rob 25			as RS11		Alternative maturity-at-length with fixed lower h values
Changes in the future					
Rob 37			as RS11		Decrease in K in the future (30% linear decrease between 2011 and 2016 for both spp)

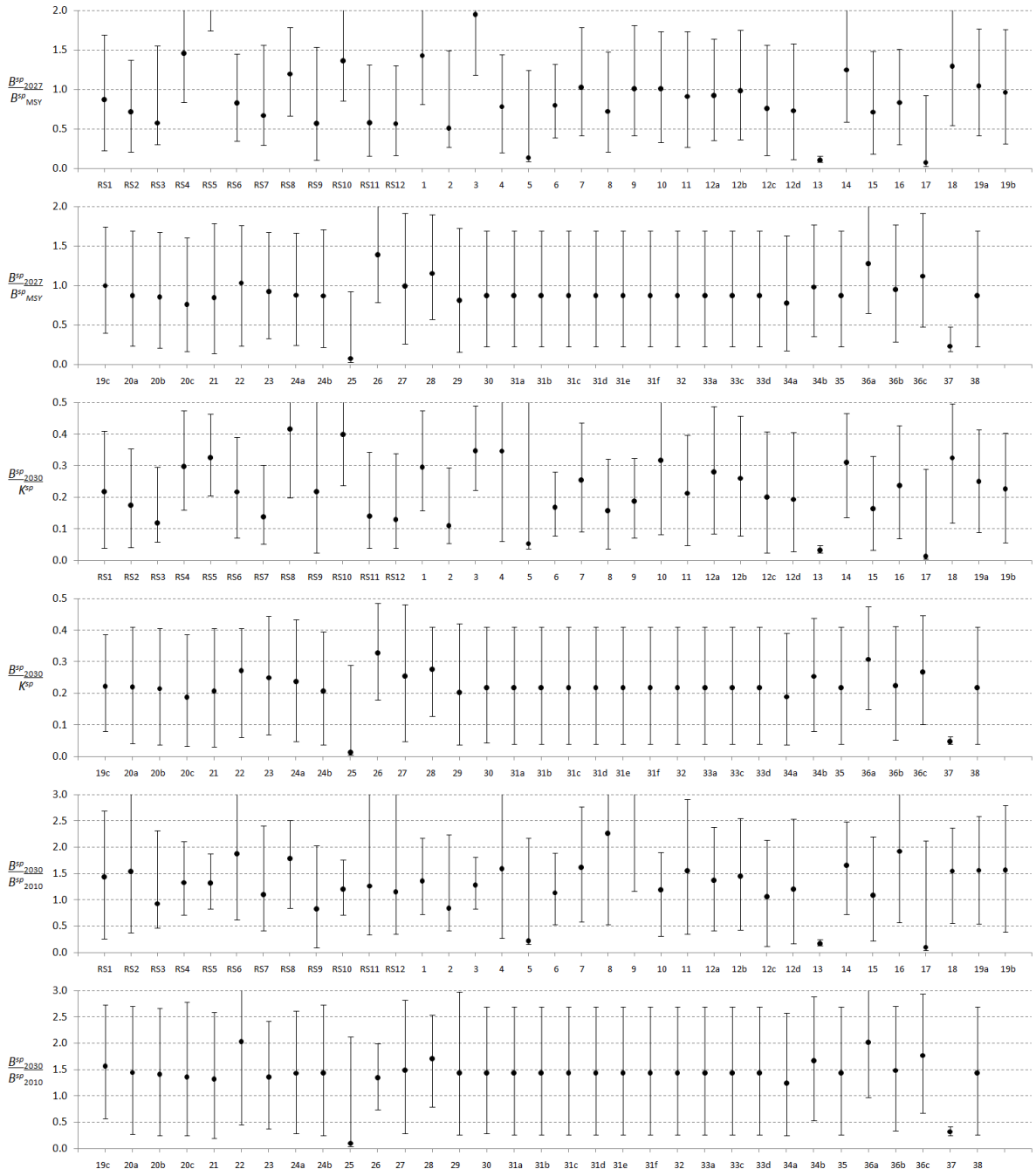

Fig. App.A.1a: Three performance statistics ($B^{sp}_{2027}/B^{sp}_{MSY}$, B^{sp}_{2030}/K^{sp} and $B^{sp}_{2030}/B^{sp}_{2010}$, in terms of female biomass only) for ***M. paradoxus*** for the full set of RS and robustness tests under a projected constant catch of **150 000t**. In some instance, the statistics are outside the area covered by the plot.

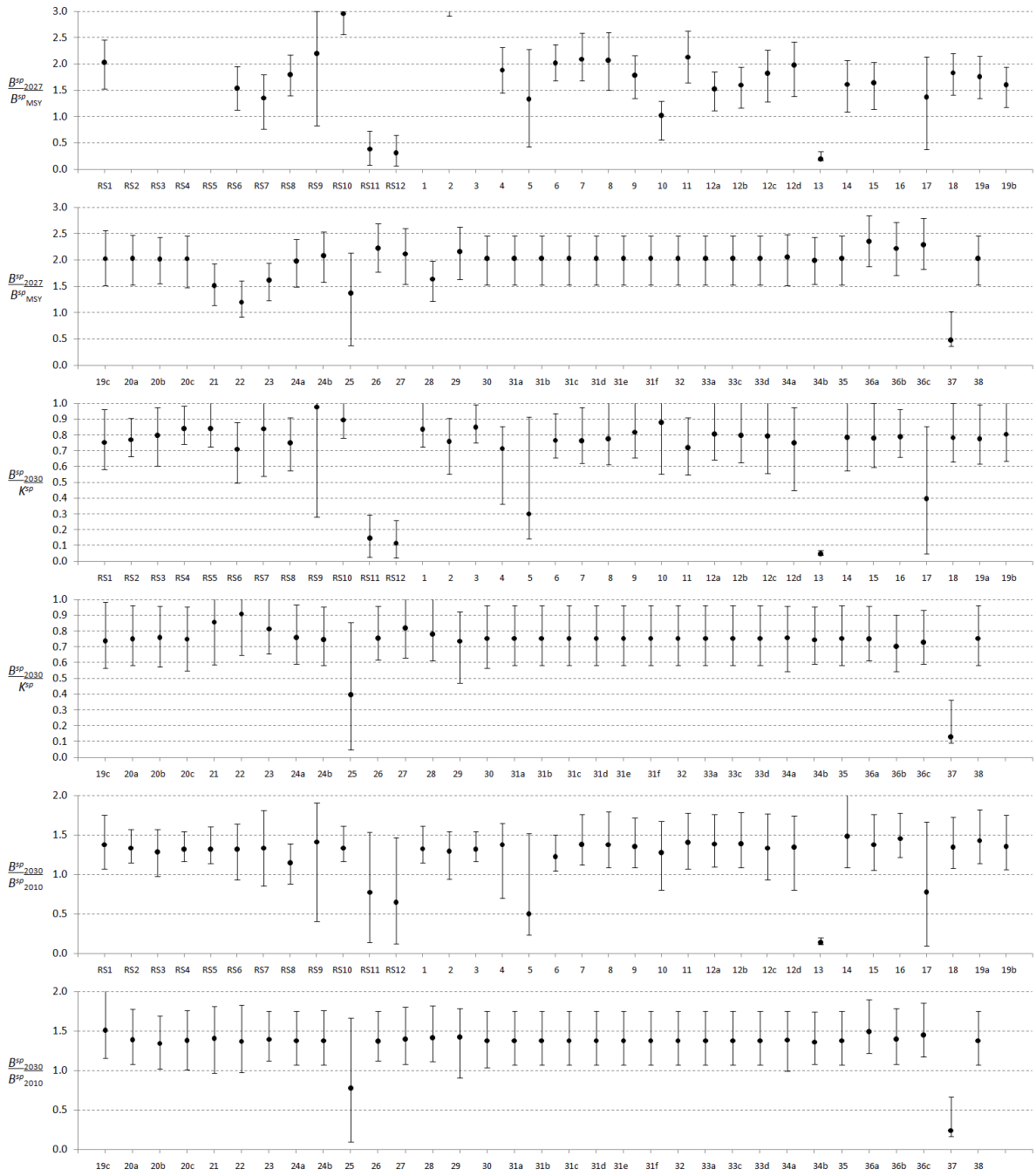

Fig. App.A.1b: Three performance statistics ($B^{sp}_{2027}/B^{sp}_{MSY}$, B^{sp}_{2030}/K^{sp} and $B^{sp}_{2030}/B^{sp}_{2010}$, in terms of female biomass only) for ***M. capensis*** for the full set of RS and robustness tests under a projected constant catch of **150 000t**. In some instance, the statistics are outside the area covered by the plot.

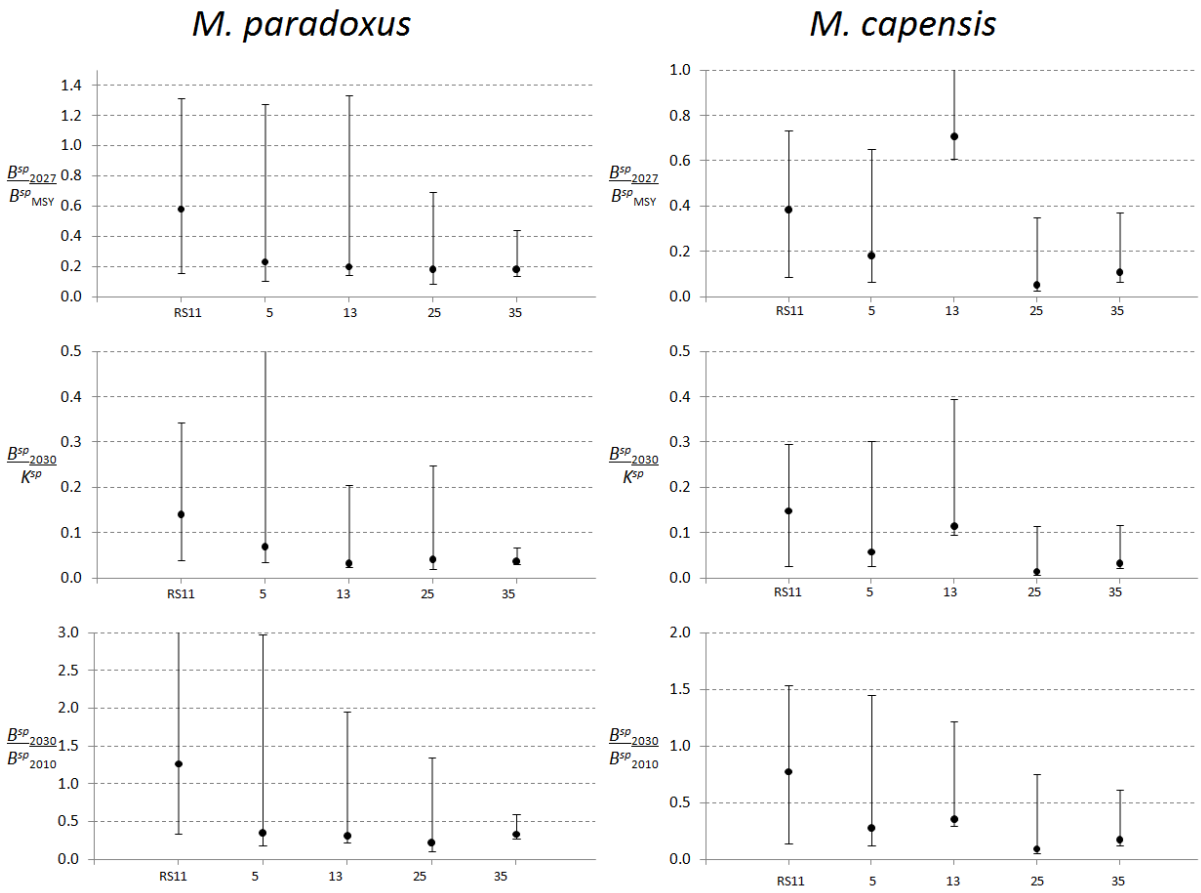

Fig. App.A.2: Three performance statistics ($B^{sp}_{2027}/B^{sp}_{MSY}$, B^{sp}_{2030}/K^{sp} and $B^{sp}_{2030}/B^{sp}_{2010}$, in terms of female biomass only) for *M. paradoxus* and *M. capensis* for RS11 and four robustness tests based on this OM under a projected constant catch of **150 000t**.