# Results of Trials of Candidate OMPs for the South African Hake Resource

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## ABSTRACT

The anticipated performance, in terms of catch and risk of resource depletion, of two candidate OMPs for the South African hake resources (each with three different resource recovery tunings) is evaluated. Both OMPs are empirically-based, given that this form of OMP has outperformed all production-model based approaches attempted to date. One of the candidate OMPs also attempts to react more quickly to recent productivity trends by including a recruitment index. These candidate OMPs are then tested over a set of robustness trials. The candidate OMPs appear reasonably robust over the fairly wide range of scenarios considered in these trials.

## INTRODUCTION

This paper presents a range of candidate OMPs for the South African hake resources, which are subjected to a Reference Set (RS) and also a set of robustness trials.

These OMPs are all of an empirical nature. Attempts to develop simple model-based procedures did not achieve success, in that performances were not superior to those of empirical approaches, so it was decided to focus on the latter.

## METHODS

The simulation-testing framework utilised is detailed in WG document WG/09/05/D:H:30. Note that this uses actual CPUE data to 2003, actual survey data to 2004, actual catch data to 2003 and assumes catches from 2004-2006 have or will equal TACs. The proportional split of the 2004 TAC by species is assumed to be identical to the actual split for 2003. Thereafter the species split of the TAC is as determined by the operating model; the testing framework assumes this split to be know without error.

Two empirically-based candidate OMPs with slightly different structures are proposed here. OMP1 is based on the recent trends in CPUE and survey indices only, while OMP2 attempts to also react more quickly to recent trends in productivity by including a recruitment index as well.

## Candidate OMP1:

The formula for computing the TAC recommendation is as follows[1]:

$$TAC_y = C_y^{para} + C_y^{cap} \tag{1}$$

with

$$C_y^{spp} = C_{y-1}^{*spp}\left[1+\lambda_y\left(s_y^{spp} - target^{spp}\right)\right] \qquad \text{if } y \le 2004+\text{Y} \quad \text{and}$$

$$C_y^{spp} = C_{y-1}^{*spp}\left[1+\lambda_y\left(s_y^{spp}\right)\right] \qquad \text{if } y > 2004+\text{Y} \tag{2}$$

where

$TAC_y$ is the total TAC recommended for year *y*,

$C_y^{spp}$ is the intended species-disaggregated TAC for year *y*,

$C_{y-1}^{*spp}$ is the achieved catch of species *spp* in year *y*-1

$\lambda_y$ is a year-dependent tuning parameter,

Y is a tuning parameter,

$target^{spp}$ is the target rate of increase for species *spp*, and

$s_y^{spp}$ is a measure of the immediate past trend in the abundance indices for species *spp* as available to use for calculations for year *y*.

This trend measure is computed as follows from the species-disaggregated GLM-CPUE ($I_y^{CPUE,spp}$), west coast summer survey ($I_y^{surv1,spp}$) and south coast autumn survey ($I_y^{surv2,spp}$) indices:

- linearly regress $\ln I_y^{CPUE,spp}$ vs. year *y'* for $y' = y-p-2$ to $y' = y-2$, to yield a regression slope value $s_y^{CPUE,spp}$,
- linearly regress $\ln I_y^{surv1,spp}$ and $\ln I_y^{surv2,spp}$ vs. year *y'* for $y' = y-p-1$ to $y' = y-1$, to yield two regression slope values $s_y^{surv1,spp}$ and $s_y^{surv2,spp}$,

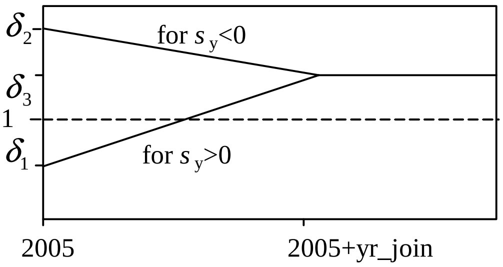
where *p* is the length of the periods considered for these regressions. Note that the reason the trend for surveys is calculated for a period moved one year later than for CPUE is that by the time of year that the TAC recommendation would be computed for the following year, survey results for the current year would be known, but not CPUE as fishing for the year would not yet have been completed.

Then

$$s_y^{spp} = \left(\frac{s_y^{CPUE,spp}}{2} + \frac{s_y^{surv1,spp}}{4} + \frac{s_y^{surv2,spp}}{4}\right) \tag{3}$$

[1] The TACs for *y*=2004-2006 are input, rather than computed by the formulae that follow. For 2004 the species split of this catch is assumed equal to that in 2003. For 2005, 2006 and following years the achieved catch for each species $C^{*spp}$ is as generated by the operating model on the basis of assumptions concerning the ratio of fishing mortalities for each fleet.

The function for the year-dependent tuning parameter, $\lambda_y$, which is a measure of how responsive the candidate OMP is to change in trend, is shown below:




**Candidate OMP2:**

For this candidate OMP, the survey abundance indices are split into an index of recruitment ($B^{i,spp}_{2-,y}$ - age 2 and below) and an index of abundance of older fish ($B^{i,spp}_{3+,y}$ - age 3 and above, which relates more closely to the age range selected by the trawl fisheries). These two indices are computed as follows from the survey catch-at-age and the survey biomass estimates (the species subscript has been omitted to reduce clutter):

1) the age-structured data from the surveys are in the form of proportions by numbers in each age class ($p^{N,i}_{y,a}$);

2) these are converted to proportions by mass in each age class ($p^{M,i}_{y,a}$) by using the mean weight-at-age:

$$p^{M,i}_{y,a} = \frac{p^{M,i}_{y,a} w_a}{\sum_{a'}^{a=m} p^{M,i}_{y,a'} w_{a'}}$$

where $w_a$ is taken as the mean begin-year weight at age *a* for the summer surveys (*i*=1) and the mean mid-year weight at age *a* for the autumn surveys (*i*=2) (see Table 1);

3) the two indices for survey *i* are then computed as:

$$B^i_{2-,y} = \sum_{a=0}^{2} p^{M,i}_{y,a} I^{survi}_y \quad \text{and} \quad B^i_{3+,y} = \sum_{a=3}^{m} p^{M,i}_{y,a} I^{survi}_y \tag{4}$$

In generating the observed $B^i_{2-}$ and $B^i_{3+}$ values, observation errors were introduced into the proportion by number-at-age ($p^{N,i}_a$) as well as the survey indices ($I^{survi}$). Lognormal errors were add to this expected values of the former with age-dependent variances as estimated in the model-fitting process, with the proportions thus generated renormalised each year to sum to 1.

The catch for each species is then computed as follows:

$$C^{spp}_y = C^{spp}_{y-1}\left[1 + \lambda_y\left(S^{spp}_y - target^{spp}\right) + \mu\left(\mathrm{Rec}^{spp}_y - 1\right)\right] \tag{5}$$

where

$S^{spp}_y$ is a measure of the immediate past trend in the abundance indices of older fish for species *spp* as available to use for calculations for year *y*, which is computed as is $s^{spp}_y$, but using $B^{i,spp}_{3+,y}$ instead of $I^{survi,spp}_y$;

$\mu$ is a tuning parameter, and

$\text{Rec}_y^{spp}$ is a relative measure of recruitment for species *spp* as available to use for calculations for year *y*.

This recruitment measure is computed as follows from the west coast summer survey data ( $B_{2-,y}^{surv1,spp}$ ):

$$\text{Rec}_y^{spp} = \frac{\frac{1}{3}\sum_{y^*=y-3}^{y-1} B_{2-,y^*-1}^{surv1,spp}}{\frac{1}{11}\sum_{y'=1994}^{2004} B_{2-,y'}^{surv1,spp}} \tag{6}$$

Thus the role of the "recruitment" term in equation (5) is to move the TAC up or down according as the average recruitment over the last three years is above or below the average over the 1994-2004 period.

Furthermore, for both OMP1 and OMP2, a maximum permissible change in TAC of **5%** from one year to the next is applied.

# RESULTS

## OMP1 vs OMP2

20-year projections have been run for the Reference Set for a series of candidate OMPs. Results are presented for three recovery tunings of each of OMP1 and OMP2. These three tunings achieved median final depletions for *M. paradoxus* of approximately 20, 30 and 40% (of $K^{sp}$) in 2025. The tuning parameters of each of these candidate OMPs are given in Table 2.

A summary of the performance statistics for each of these candidate OMPs is given in Fig. 1. All three tunings of OMP2 show greater average variation in TACs than the OMP1 variants. Otherwise, for the same level of *M. paradoxus* recovery, the two candidate OMPs seem to perform very similarly for the Reference Set.

Figs 2a and 2b show trajectories of resource abundance and catch for an application of candidates OMP1b and OMP2b respectively (the central recovery tunings) to the whole RS, while Figs 3a and 3b shows these trajectories for the SR2 scenarios of the RS only.

Fig. 4 compares the TAC trajectories for candidate OMP1b and OMP2b if all future indices (CPUE from 2004 and surveys from 2005) stayed constant at recent levels over the 20-year projection period. The CPUEs have been fixed at the average of the 2001-2003 values, and the survey biomass and catch-at-age estimates have been fixed to the average over the 2002-2004 period. It is clear that if these indices do not increase in the future, the TAC will decrease at a rate close to the maximum permissible (5% per annum) under both candidate OMPs.

## SR1 vs SR2

Median projections of resource abundance and catch are compared for the SR1 and SR2 scenarios of the RS for an application of candidate OMP1b and candidate OMP2b in Fig. 5a and 5b respectively.

## Robustness trials

A summary of performance statistics for candidate OMP1b and OMP2b for each of the robustness trials is given in Fig. 6.

# DISCUSSION

The intent underlying OMP2 was that by taking more immediate action in response to indications of recruitments being above or below average levels of the last decade, target recovery levels would be more closely attained, with catches raised or lowered correspondingly and appropriately. However there is very little difference in comparable 90% ranges for final depletion for *M. paradoxus* for OMP1 and OMP2 (see for example Fig. 1). It would appear that any advantage in principle that use of recruitment estimates in setting TACs would appear to provide is offset by the poor precision with which such recruitments can be estimated from survey results. The only scenarios where OMP2 might be argued to perform somewhat better than OMP1 is when $K$ changes over time (see Figs 5a and 5b) – interestingly these seem the only scenarios for which recovery performance is much worse than that for the RS. The effect of changing the maximum permissible decrease in TAC from one year to the next from 5% to 10% and to no limit is shown in Fig. 7 for the RS and for the robustness trial in which $K$ changes in the past (A4). It is clear that a maximum permissible decrease of 10% is still not sufficient to prevent possible *M. paradoxus* extinction in the A4 robustness trial.

It is important to note that these results are based on data up until the 2003 CPUE and 2004 surveys. At this time, two years further data from each of these sources are available and would be used in actual implementation of any of these candidates OMPs (in contrast to the stochastic model projections upon which the results presented here are based).

Within the range of options presented here, the factors between which choices would have to be made are:

a) whether or not to use a recruitment index from the west coast survey (i.e. OMP1 or OMP2);

b) what depletion recovery target to select for *M. paradoxus* (which relates to the rate of CPUE recovery desired); and

c) possible constraints to impose on the maximum extent of TAC variability from one year to the next (currently 5%).

Given that future performance is sensitive to whether the SR1 or SR2 recruitment scenario applies, it might be desirable to advance assessments using data that have become available since the corresponding operating models were fixed to better determine what earlier were the most recent recruitments, and hence to use other than equal weighting for SR1 and SR2 in integrating over the RS and then tuning to recovery targets.

Simulations conducted to date have assumed that the species split of the current year's catch ($C^{*spp}_{y-1}$) is known at the stage of computing the TAC for next year ($TAC_y$) (see equations 1 and 2). In practice, however, the most recent information on species split available at that time would be for year $y$-2 as fishing for year $y$-1 would not yet have been completed. To allow for this when final tuning is effected, trials will implement equation (2) by setting $C^{*para}_{y-1} + C^{*cap}_{y-1}$ to $TAC_{y-1}$, but assuming the proportional split by species to be the same as for $y$-2. (This change would not be expected to have other than a minor impact on the results reported here). Note that in actual OMP implementation, equation (2) will be based on the TAC for $y$-1, not the anticipated total catch for that year. Thus actual implementation for 2007 will specify $C^{*para}_{2006}$ and $C^{*cap}_{2006}$ by having these sum to 150 000 tons, and with a ratio as estimated for the 2005 total catch.

# OTHER FUTURE WORK

Other matters which need to be finalised before a revised OMP proposal can go forward are:

a) procedures if certain OMP input data are not available, or deemed unsatisfactory, in a particular year; and

b) finalisation of OMP metarule and review/revision procedures.

Clearly neither OMP1 or OMP2 as at present perform satisfactorily in circumstances where *K* has decreased or will decrease overtime. Results in Fig.. 7 suggests that this problem can be resolved by increasing the extent to which the TAC can be reduced from one year to the next if resource indices fall below specified thresholds. Such modifications might be considered to be of an Exceptional Circumstances (metarule) nature; as they are unlikely to greatly affect performance in other trials, their finalisation could perhaps be delayed until after the basic OMP has been adopted and implemented to provide a recommendation for a TAC for 2007.

After the OMP is finalised, further work will be needed to clarify what changes might result in response to data from the current experimental study on vessels checking the species composition of the catch against the (primarily) depth-related algorithm in current use.

**Table 1**: Begin-year and mid-year mean weights-at-age assumed for the computation of $B_{2-,y}^{i,spp}$ and $B_{3+,y}^{i,spp}$, from the von Bertalanffy growth and mass-at-length equation parameter values estimated by Punt and Leslie (1991).

| | *M. paradoxus* | | *M. capensis* | |
|---|---|---|---|---|
| | Begin-year | Mid-year | Begin-year | Mid-year |
| 0 | 6 | 22 | 3 | 14 |
| 1 | 54 | 105 | 38 | 81 |
| 2 | 180 | 281 | 148 | 243 |
| 3 | 412 | 573 | 369 | 530 |
| 4 | 766 | 993 | 729 | 968 |
| 5/5+ | 1773 | 1895 | 1249 | 1574 |
| 6 | | | 1945 | 2361 |
| 7+ | | | 3536 | 3692 |

Note: The plus-group weights ( $w_z^{spp}$ ) have been somewhat arbitrarily computed using a weighted average:

Begin-year: $w_z^{spp} = \sum_{a=z}^{15} \hat{p}_a^{surv1} w_a^{spp}$ and mid-year: $w_z^{spp} = \sum_{a=z}^{15} \hat{p}_a^{surv2} w_{a+1/2}^{spp}$

where

$\hat{p}_a^{survi}$ is the predicted proportion of fish of age *a* in survey *i* (*i*=1, West coast summer survey; *i*=2, South coast autumn survey), as average over all years available and Reference Set scenarios 1, 4, 5 and 8 (M1-H1-C3-SR1, M1-H4-C3-SR1, M4-H1-C3-SR1 and M4-H4-C3-SR1).

**Table 2**: Tuning parameters for each candidate OMPs presented in this paper. $\delta_1$, $\delta_2$ and $\delta_3$ are the parameters of the year-dependent tuning parameter, $\lambda_y$ .

| | $p$ | $\delta_1$ | $\delta_2$ | $\delta_3$ | Yr_join | target para | target cap | Y |
|---|---|---|---|---|---|---|---|---|
| OMP1a | 5 | 0.1 | 4 | 1.1 | 10 | 7.0% | 0% | 13 |
| OMP1b | 5 | 0.5 | 2 | 1.1 | 10 | 5.0% | 0% | 10 |
| OMP1c | 5 | 1.1 | 1.5 | 1.1 | 10 | 0.0% | 0% | 10 |

| | $p$ | $\delta_1$ | $\delta_2$ | $\delta_3$ | Yr_join | target para | target cap | Y | $\mu$ |
|---|---|---|---|---|---|---|---|---|---|
| OMP2a | 5 | 3 | 3 | 3 | 10 | 5.0% | 0% | 10 | 0.2 |
| OMP2b | 5 | 3 | 3 | 3 | 10 | 1.5% | 0% | 10 | 0.1 |
| OMP2c | 5 | 5 | 2 | 3 | 15 | 0.0% | 0% | 10 | 0.03 |

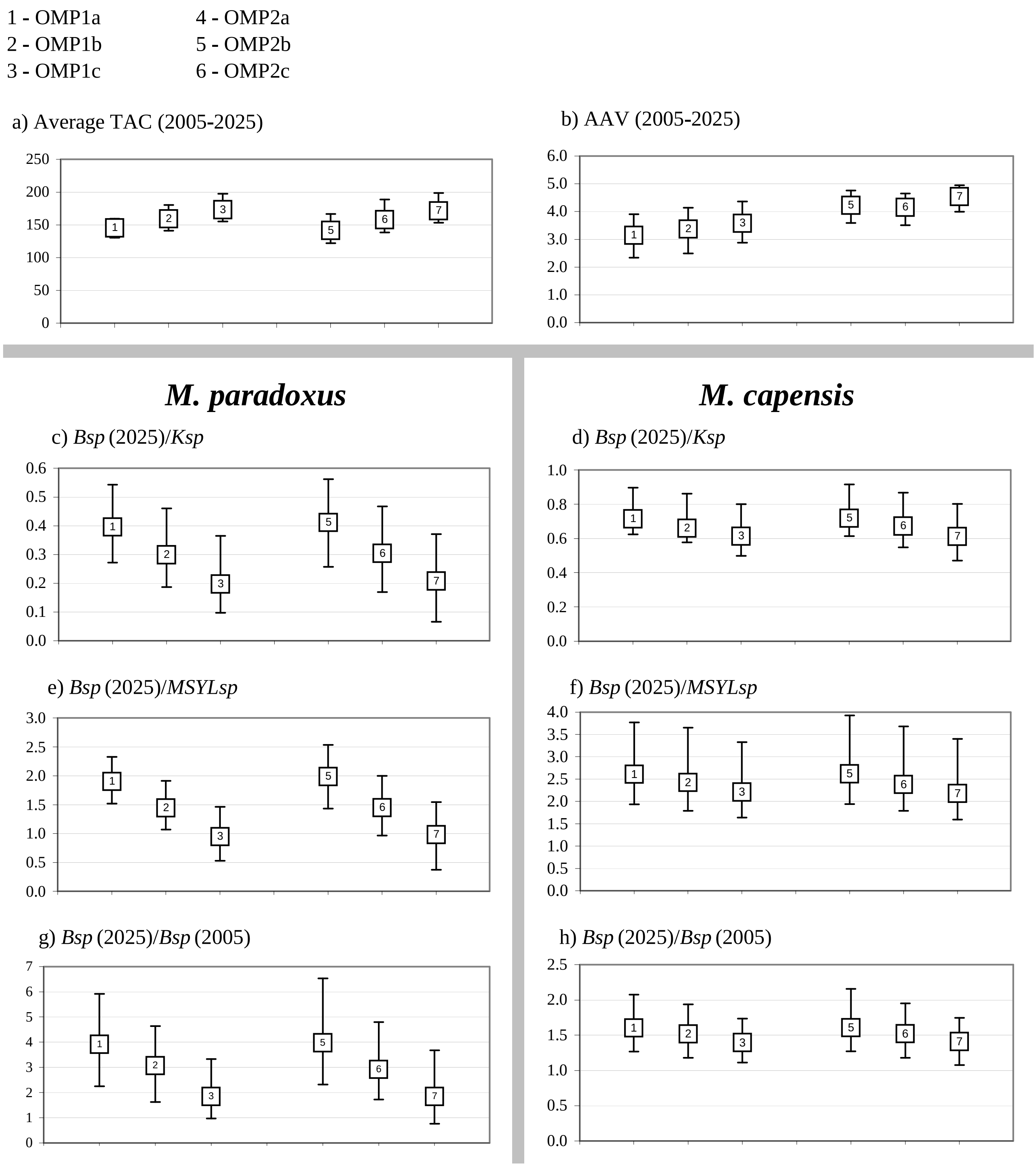



**Fig. 1**: Graphical summary of performance statistics for three versions of candidate OMP1 and candidate OMP2, tuned to three different recovery levels for *M. paradoxus*, for the RS. Each panel shows medians together with 90% PIs

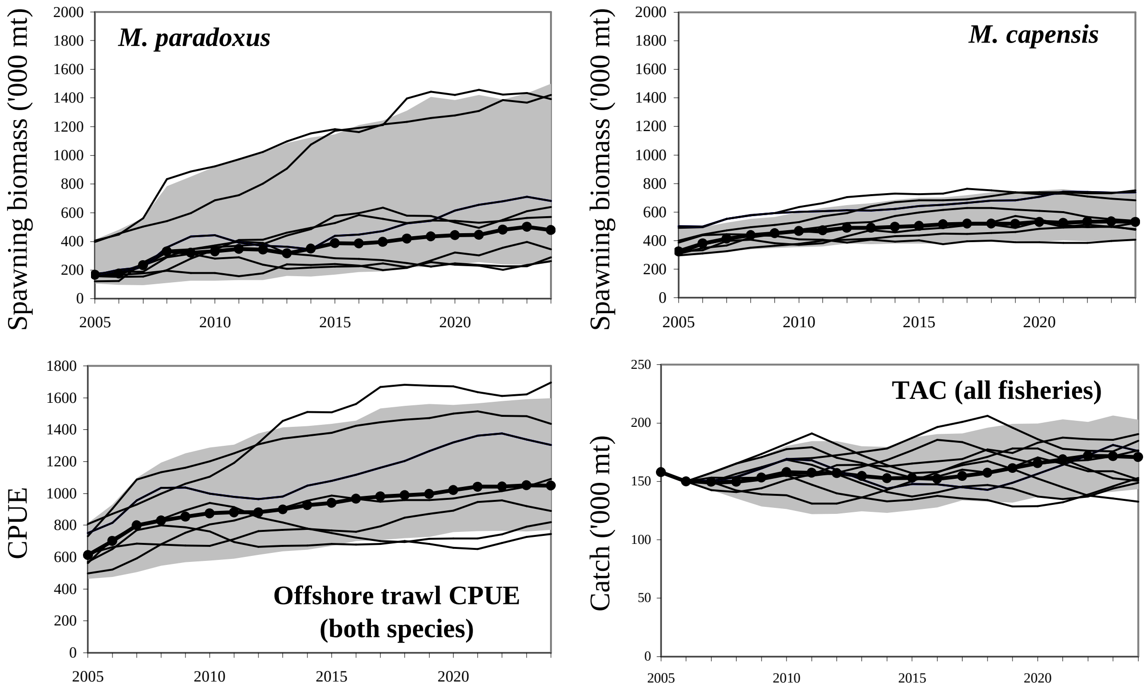



**Fig. 2a**: Trajectories of resource abundance and catch for an application of candidate **OMP1b** to the RS. Here and below, ten individual trajectories are shown, with the median a dark dotted line; the shaded areas show 90% probability envelopes. Note units for CPUE are those of the exploitable biomass to which it corresponds.

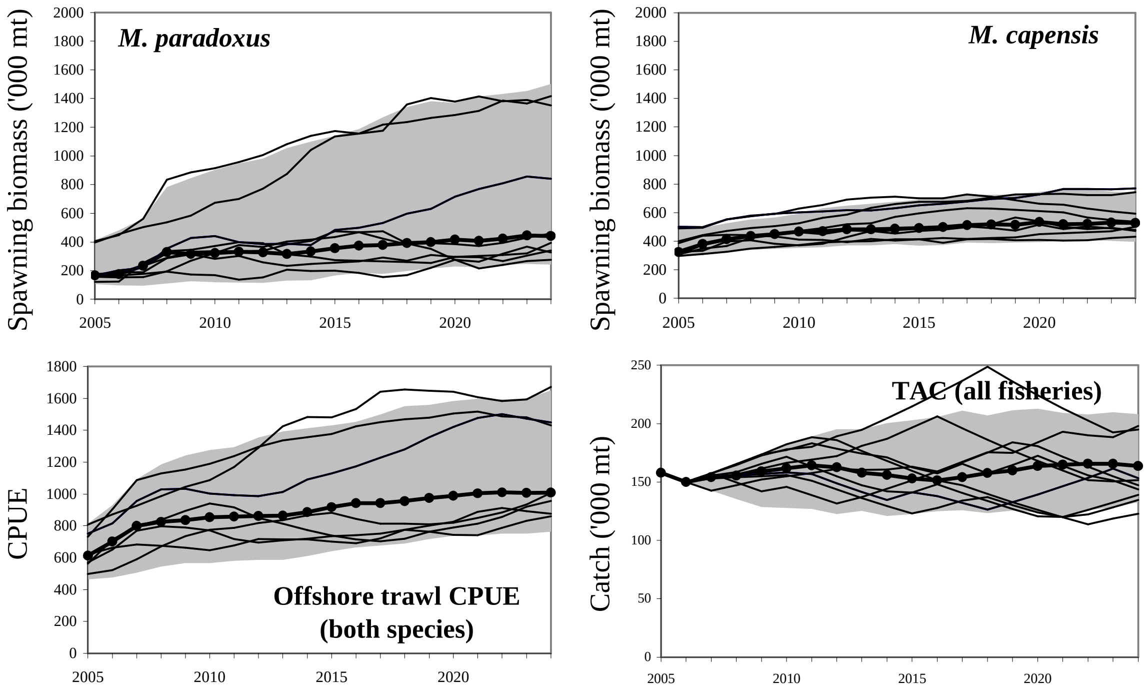



**Fig. 2b**: Trajectories of resource abundance and catch for an application of candidate **OMP2b** to the RS. Note units for CPUE are those of the exploitable biomass to which it corresponds.

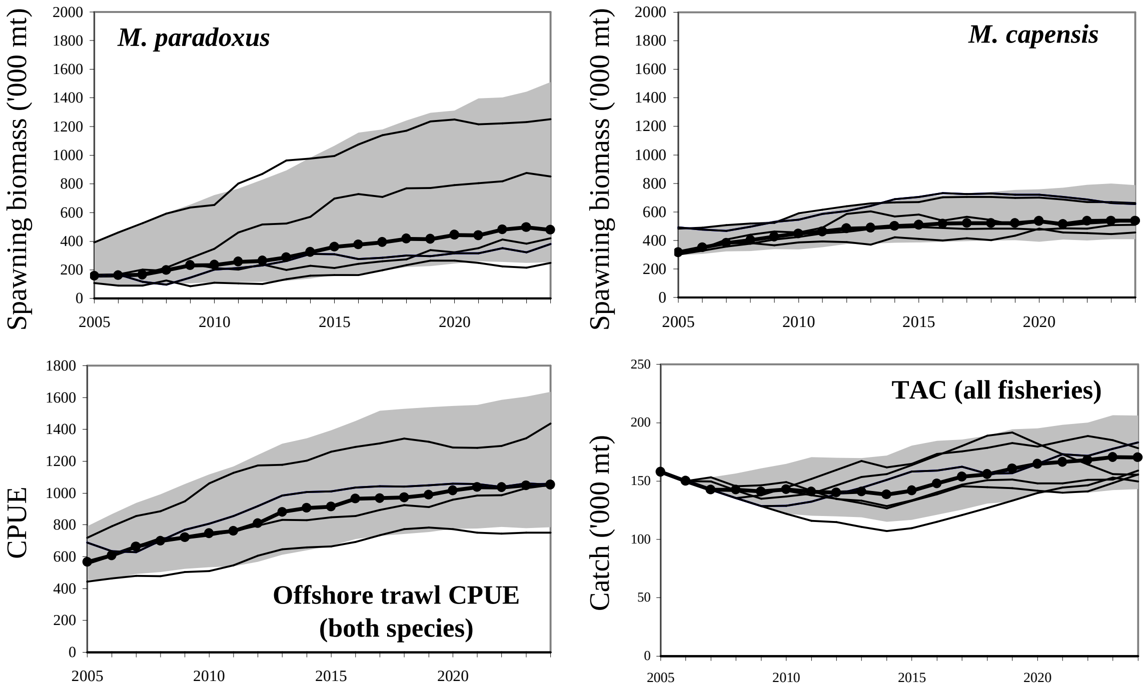



**Fig. 3a**: Trajectories of resource abundance and catch for an application of candidate **OMP1b** to the **SR2** scenarios of the RS. Note units for CPUE are those of the exploitable biomass to which it corresponds.

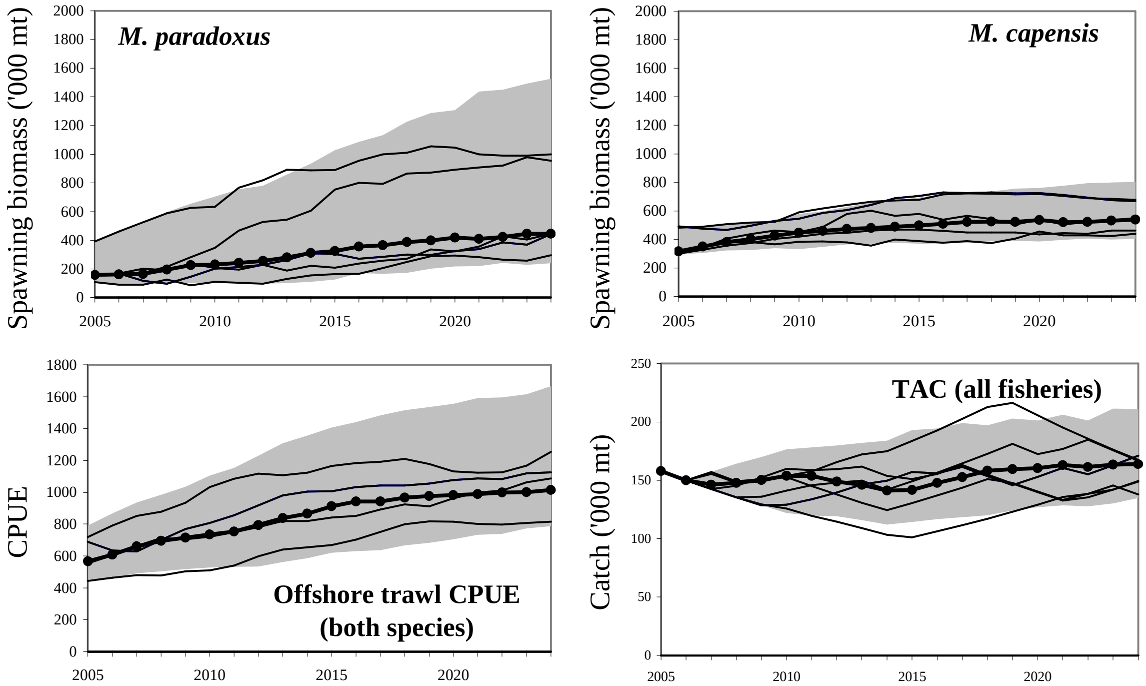



**Fig. 3b**: Trajectories of resource abundance and catch for an application of candidate **OMP2b** to the **SR2** scenarios of the RS. Note units for CPUE are those of the exploitable biomass to which it corresponds.

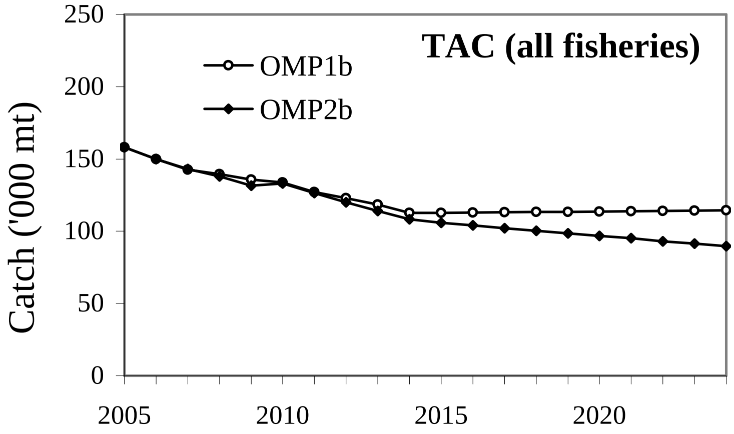



**Fig. 4**: Comparison of catch trajectories (medians) for an application of candidate **OMP1b** and **OMP2b** assuming all future indices stayed constant at the average of the last three years data (2001-2003 for CPUE and 2002-2004 for surveys biomass and catch-at-age estimates).

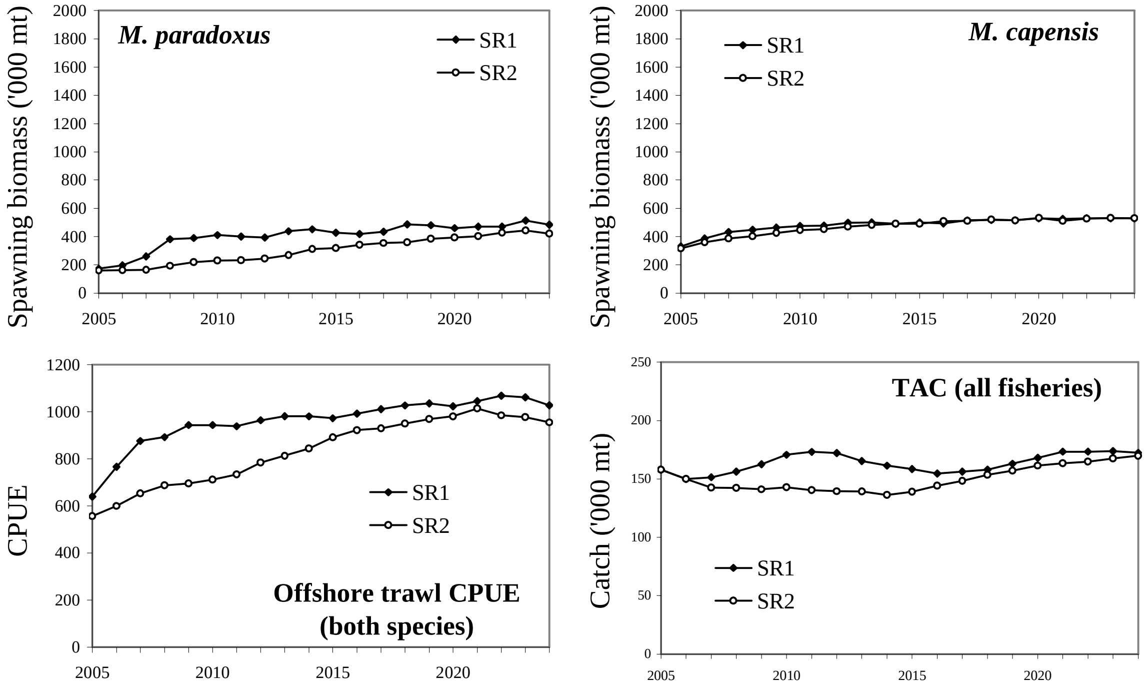



**Fig. 5a**: Resource abundance and catch (medians) for an application of candidate **OMP1b** to a) only the **SR1** scenarios of the RS and b) only the **SR2** scenarios. Note units for CPUE are those of the exploitable biomass to which it corresponds.

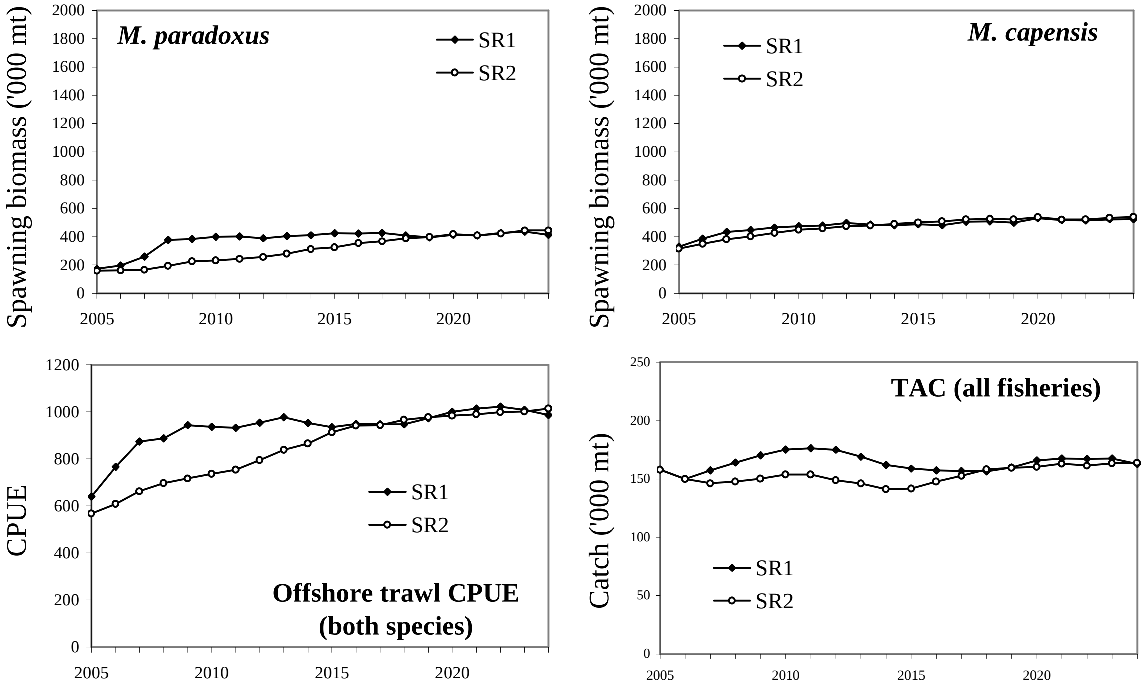



**Fig. 5b**: Resource abundance and catch (medians) for an application of candidate **OMP2b** to a) only the **SR1** scenarios of the RS and b) only the **SR2** scenarios. Note units for CPUE are those of the exploitable biomass to which it corresponds.

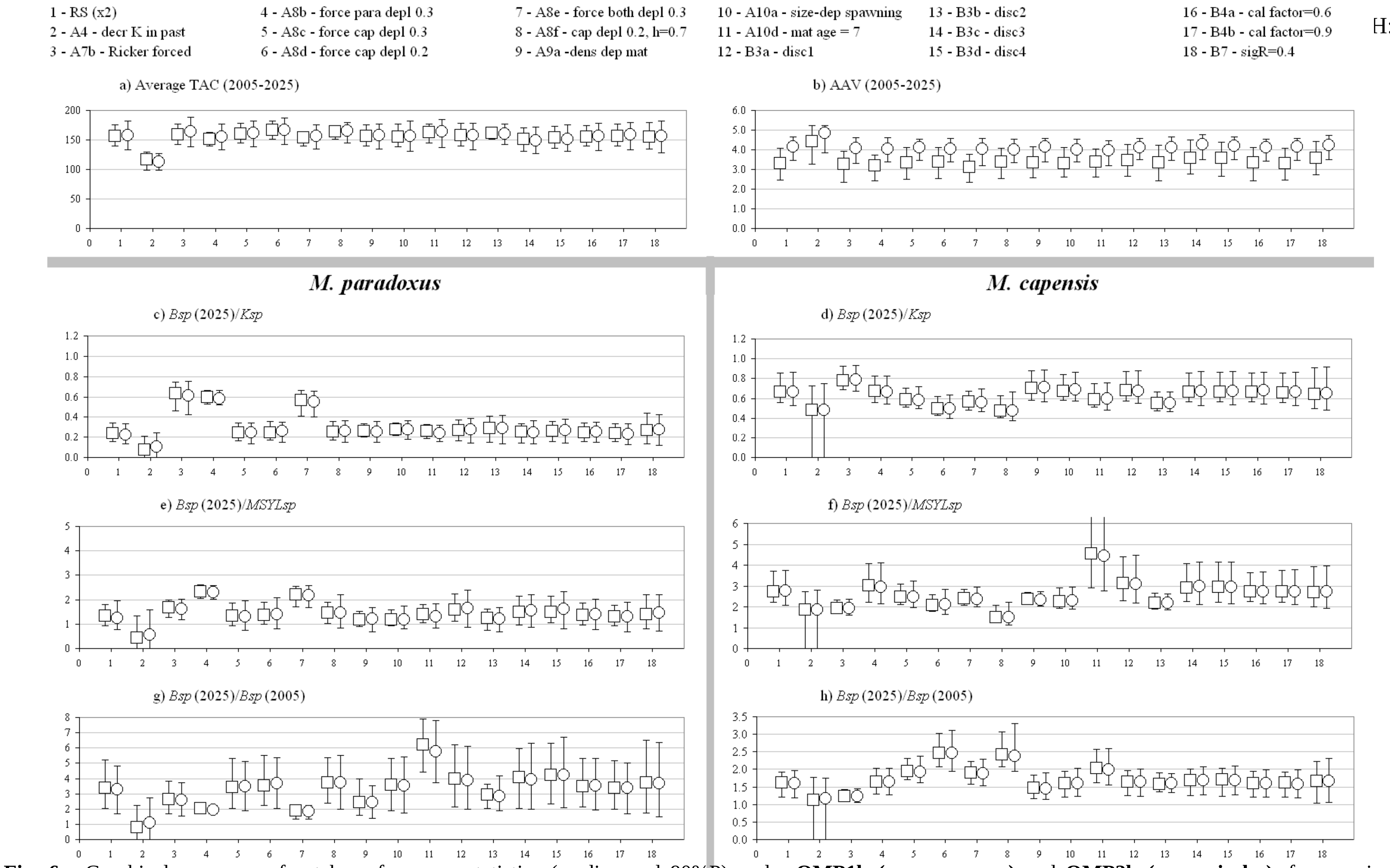



**Fig. 6a**: Graphical summary of catch performance statistics (median and 90%P) under **OMP1b (open squares)** and **OMP2b (open circles)**, for a series of robustness tests, for two scenarios (M1-H1-C3-SR2 and M4-H1-C3-SR2) within the RS. In the scenario in which the $K^{sp}$ decreases (A4), the $K^{sp}$ used to compute $B^{sp}(2005)/K^{sp}$ is the current (2005) estimate.

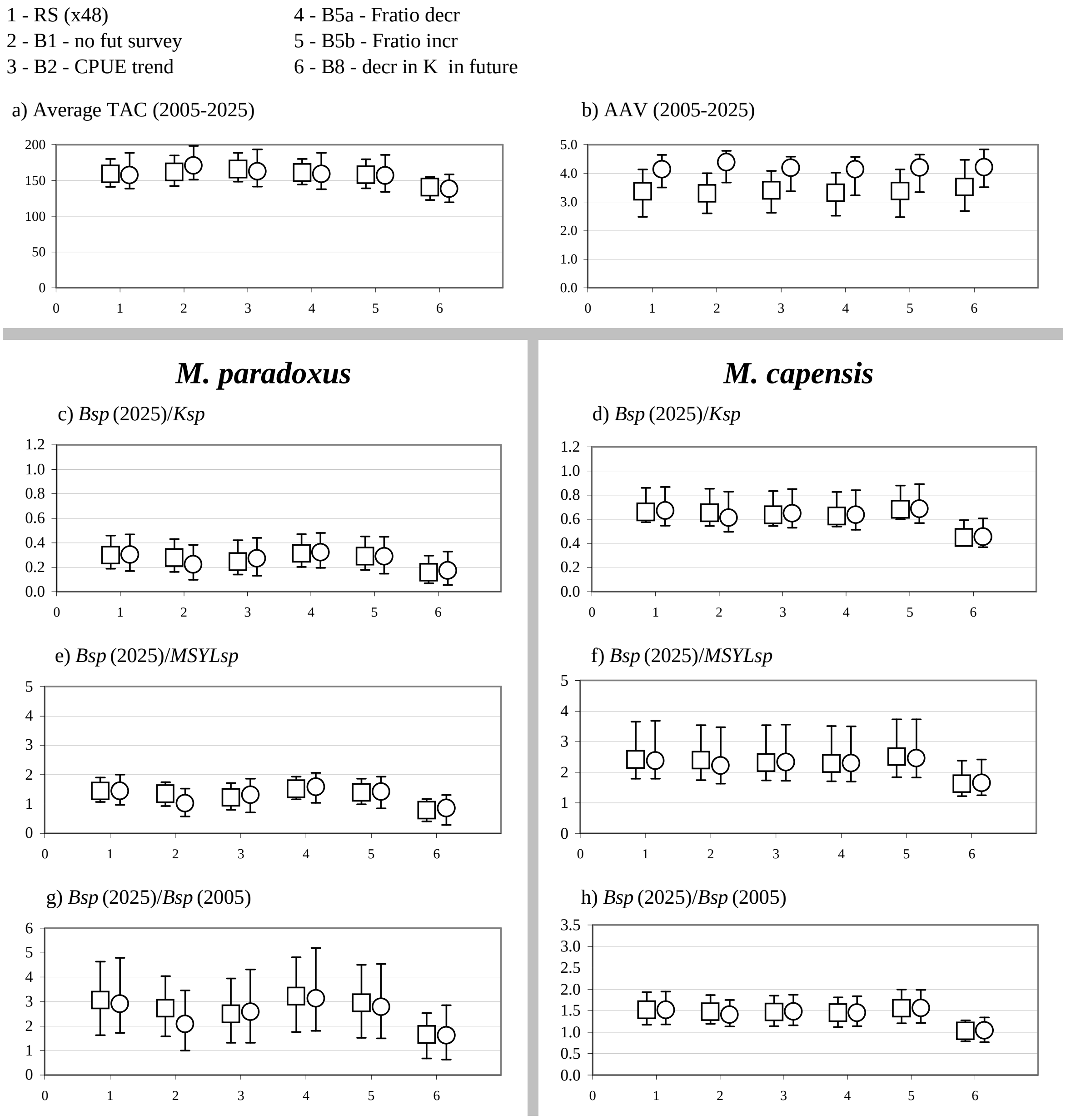



**Fig. 6b**: Graphical summary of catch performance statistics (median and 90% PI) under **OMP1b (open squares)** and **OMP2b (open circles)**, for a series of robustness tests, for all 48 scenarios of the RS. In the absence of future survey (and associated catch-at-age) data, the measure of the immediate past trend in the abundance indices ( $s_y^{spp}$ ) in OMP1 and OMP2 is computed using the CPUE only and the recruitment index ( $\mathrm{Rec}_y^{spp}$ ) in OMP2 is set to 1 so that there is no correction for recruitment. In the scenario in which $K^{sp}$ decreases (A4), the $K^{sp}$ uses to compute $B^{sp}(2005)/K^{sp}$ is the current (2005) estimate.

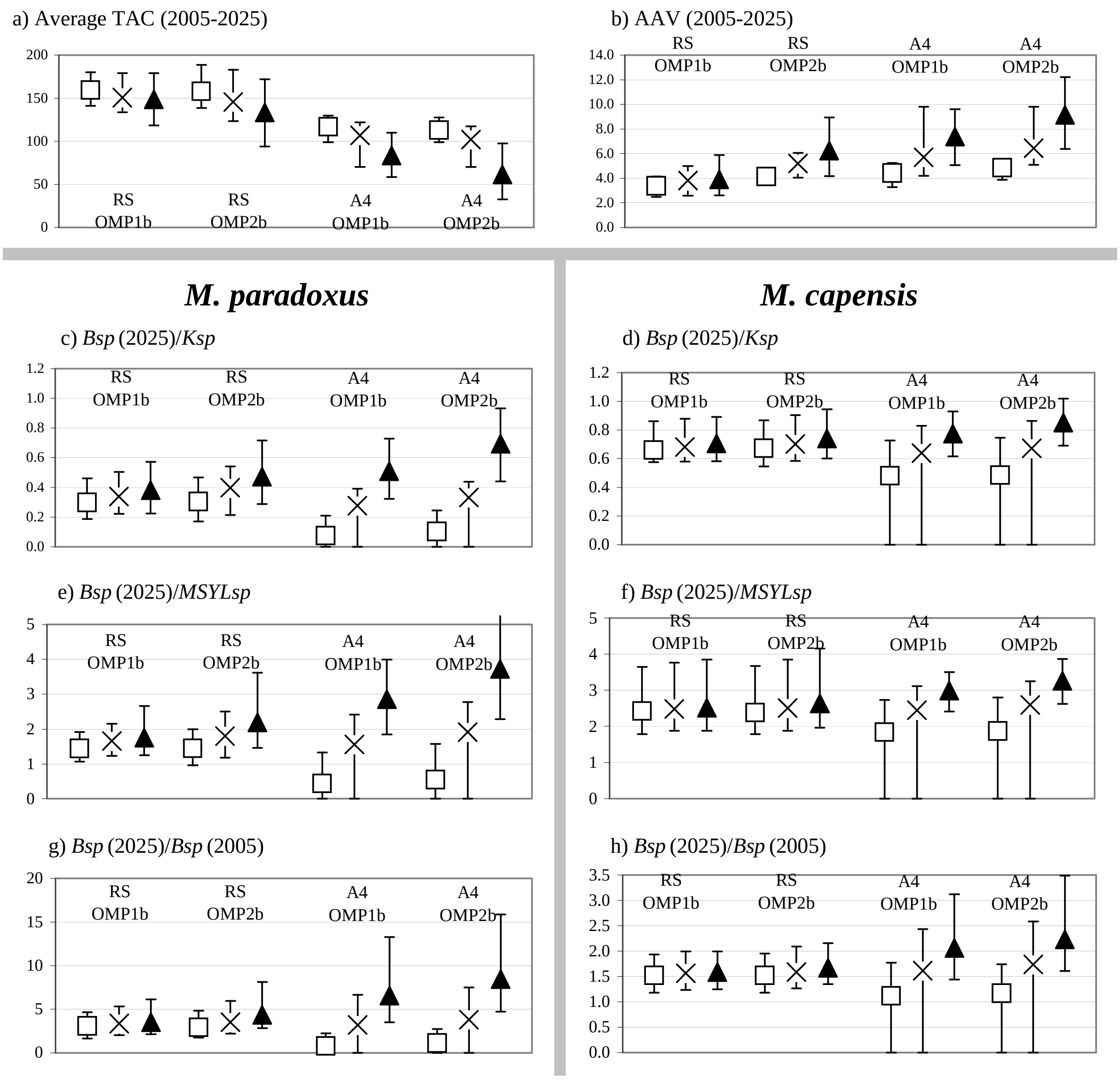



**Fig. 7**: Graphical summary of catch performance statistics (median and 90% PI) under **OMP1b** and **OMP2b**, for the RS (all 48 scenarios) and robustness test A4 in which $K^{sp}$ is decreased in the past, for three levels of maximum permissible decrease from one year to the next: a) 5% (open squares), b) 10% (crosses) and c) no limit (full triangles). In all cases, the maximum permissible increase is 5%.