Hake projections with missing surveys under OMP2022

A. Ross-Gillespie, D.S. Butterworth and T. Maphumulo[1]

Contact email: andrea.ross-gillespie@uct.ac.za

Summary

The Hake RC OM is projected forward under the rules of OMP2022 for various assumptions regarding future surveys. The main impact of no future surveys is to reduce the range of predicted TACs over the next four years, but also to lower the expected TAC. Modelling an undetected catchability increase results in slightly higher TACs and lower biomasses, the latter being a concern at the lower 5th percentile of the projections only. However, the scenarios modelling an undetected catchability increase estimates a gradual decrease in the *M. paradoxus* population over time, highlighting the importance of the survey indices as a safeguard against such an occurrence. Overall, the current OMP appears to be able to deal with the different assumptions regarding future surveys that have been made here, at the cost of some TAC reductions and slightly lower population levels in some cases.

Keywords: catchability, South African hake, Reference Case update, 2025 data, survey

Introduction

The hake 2025 RC is projected forward under the rules of OMP-2022, for various assumptions regarding future surveys. The five robustness tests conducted here are a repeat of those from Ross-Gillespie and Butterworth (2022), and descriptions are provided below. A description of OMP-2022 has been given in the Appendix for ease of reference.

*RT1: No future surveys (**NS**)*

Once no survey has taken place for three consecutive years are more, the survey indices automatically receive a zero weighting in OMP catch Equations (A3) and (A4) of the Appendix for the succeeding year(s).

*RT2: All future surveys are conducted by industry vessels (**AI**)*

The standard method for generating future survey indices is:

$$I_y^{surv} = q_{surv} B_y^{surv} e^{\epsilon_y} \quad (1)$$

where I_y^{surv} is the survey index generated for year *y*, q^{surv} is the survey catchability coefficient estimated when fitting the Operating Model (OM), B_y^{surv} is the survey biomass for year *y* and e^{ϵ_y} is an error term with ϵ_y assumed to be normally distributed.

Let q_R be the catchability coefficient of the research vessel (i.e. the *Africana*) and let q_I be the catchability coefficient of the industry vessel. Let *R* be the ratio of the catchability coefficient of the industry to that of the research vessel, i.e. $R = q_I / q_R$. Winker (2018) reports that this ratio *R* is distributed with a median of 0.80 and standard error of 0.18 (the computations to come assume this distribution to be log-normal).

[1] Marine Resource Assessment and Management Group, University of Cape Town, Rondebosch, 7701

When generating future survey indices under the assumption that an industry vessel will conduct the surveys, a further error term e^{η_y} is added to equation (1) with $\eta_y \sim N(ln0.80, (0.22)^2)$ so that e^{η_y} is log-normally distributed with median of 0.80 and standard error of 0.18.[2]. Equation 1 consequently becomes:

$$I_y^{surv} = q_{surv} B_y^{surv} e^{\epsilon_y} e^{\eta_y} \tag{2}$$

The survey value generated according to Equation (2) is then divided by 0.80 before being used in the OMP formula, as this is what would be done in reality if the industry vessel were being used, given that the bias would be known.

*RT3: Two surveys (WC and SC) take place every second year only (**ES**)*

As for no future surveys, the survey indices are removed from the TAC calculation in years for which no survey is to take place, and the survey contribution is down-weighted accordingly.

*RT4: RC assumptions (i.e. all future surveys continue as normal with the research vessel) but with an undetected increase in CPUE catchability of 2% p.a. (**RC+UCI**).*

For an undetected increase in commercial catchability, a steady increase of 2% p.a. in the CPUE *q* value was assumed, as this was considered a likely extreme case scenario.

*RT5: No future surveys with an undetected increase in catchability (**NS+UCI**).*

RT1 (no future surveys) is combined with an undetected increase in commercial catchability, as for Robustness test RT4.

Note that the projections for the "RC" assume that surveys take place each year using the research vessel.

Results

Table 1 lists key biomass-related performance statistics and Table 2 does the same for the catch-related performance statistics. Figure 1a and b show Zeh plots for these performance statistics. Figure 2a to Figure 2c plot biomass and catch trajectories for the next 20 years, as well as histograms of projected TACs for the next 5 years.

Discussion

Some discussion points are listed below.

- The RC projections suggest a likely further decrease to just below B_{MSY} for *M. paradoxus*. The lower 5th percentile remains below B_{MSY} for the next 10 years, but the median projected biomass value is above B_{MSY} by about 2028 (plot (i) of the top half of Figure 2a). The *M. capensis* biomass trajectory is indicated to fluctuate slowly around the $B/B_{MSY} = 3$ mark. Projected TAC values suggest that a further 5% decrease in TAC next year is most likely, with a possible increase in TAC in the following years, although the 90% PIs span roughly 115000t to the upper cap of 160 000t (plots (iii) and (iv) of Figure 2a). Note that the 2027 TAC goes below the maximum 5% change from the 2026 TAC for some of the simulations, because the projected *M. paradoxus J* index goes below the threshold for the OMP for those simulations, thus triggering a larger interannual percentage change (see the Appendix for more details).
- The impact of no surveys (RT2) is to reduce the range of possible TACs over the next few years (probably because the only variability available to impact the calculations is that of the CPUE, given no surveys), but the TACs are generally lower than for the RC scenario for which surveys take place (bottom two rows of Figure 2a). The impact on the biomass trajectories is relatively small, suggesting that the OMP formula can cope with a no survey scenario by reducing the TACs, although of course this robustness test does not incorporate any unforeseen changes to the population.

[2] If ln*R* is normally distributed with mean μ and variance σ^2, then the median of the distribution of *R* is given by $\theta_R = e^{\mu}$ and the variance by $\sigma_R = (e^{\sigma 2} - 1)(e^{2\mu + \sigma 2})$. Since $\theta_R = 0.80$ and $\sigma_R = 0.18$, it follows that $\mu = ln0.80$ and $\sigma = 0.22$.

- The impact of using the industry vessel rather than the research vessel (RT2) is minimal (top 2 rows of Figure 2b).
- The impact of having a survey every second year (RT3) is similar to the no survey scenario (RT1) in that generally a slightly smaller range of TACs is predicted, although the impact is not as extreme as that for RT1 and the results are much more comparable to the RC (bottom two rows of Figure 2b).
- RT4 models with their undetected increase in catchability, i.e. the CPUE indices going up due to fishing-strategy-related changes, without the population biomass necessarily increasing. The impact is generally higher TACs as would be expected, with a slightly lower biomass trajectory, and the lower 5th percentile staying down at the $B/B_{MSY} = 0.8$ level (top two rows of Figure 2c).
- RT5 combines the undetected increase in catchability with no future surveys. As for RT1, the impact of no survey is to reduce the range of possible TACs, while the main impact of the undetected catchability increase is to increase the expected TACs and to lower the expected biomass slightly, in particular the lower 5th percentile values. While the RC abundances fluctuate slowly, they remain generally stable for the populations for both species; both scenarios with the undetected catchability increase indicate a gradual decrease in the *M. paradoxus* population over time, highlighting the importance of the survey indices as a safeguard against such an occurrence.

References

Ross-Gillespie, A. and Butterworth, D.S. 2022. List of robustness tests for the hake OMP-2022 revision. DFFE Fisheries document: FISHERIES/2022/AUG/SWG-DEM/14: 9pp.

Winker, H. 2018. A state-space approach to approximate changes trawl survey catchability for *Merluccius paradoxus* and *M. capensis*. DFFE document FISHERIES/2018/SEP/SWG-DEM/45. Also International Stock Assessment Workshop document MARAM/IWS/2018/Hake/BG5.

Table 1: Key **biomass-related** performance statistics for the RC and five robustness tests. Results are shown for 10-year and 20-year projections, with medians listed along with 90% PIs in parentheses. B(lowest)/B_{MSY} is the lowest level to which the trajectory goes in the 10 or the 20 year period, relative to B_{MSY}.

	B(2036)/B_{MSY}				B(lowest)/B_{MSY}			
10-year	*M. paradoxus*		*M. capensis*		*M. paradoxus*		*M. capensis*	
RC	1.93	(0.82,4.45)	3.12	(2.24,4.36)	0.89	(0.55,1.17)	2.92	(2.23,3.20)
RT1 - No surveys	2.06	(0.91,4.61)	3.18	(2.29,4.49)	0.89	(0.55,1.17)	2.95	(2.23,3.20)
RT2 - All Industry	1.91	(0.80,4.44)	3.12	(2.24,4.37)	0.89	(0.54,1.17)	2.92	(2.19,3.20)
RT3 – Every 2nd year	1.97	(0.82,4.54)	3.15	(2.25,4.37)	0.89	(0.54,1.17)	2.92	(2.21,3.20)
RT4 – UDI	1.87	(0.72,4.43)	3.09	(2.19,4.34)	0.88	(0.51,1.17)	2.89	(2.16,3.20)
RT5 – NS + UDI	1.93	(0.72,4.55)	3.12	(2.19,4.42)	0.89	(0.50,1.17)	2.91	(2.15,3.20)
	B(2046)/B_{MSY}				B(lowest)/B_{MSY}			
20-year	*M. paradoxus*		*M. capensis*		*M. paradoxus*		*M. capensis*	
RC	2.07	(1.04,3.91)	2.94	(1.94,4.35)	0.88	(0.54,1.15)	2.43	(1.79,3.02)
RT1 - No surveys	2.10	(1.09,4.06)	2.93	(1.91,4.36)	0.89	(0.53,1.15)	2.42	(1.80,3.02)
RT2 - All Industry	2.06	(1.03,3.95)	2.95	(1.94,4.37)	0.88	(0.53,1.15)	2.43	(1.79,3.02)
RT3 – Every 2nd year	2.10	(1.07,4.03)	2.95	(1.93,4.30)	0.88	(0.53,1.16)	2.43	(1.81,3.02)
RT4 – UDI	1.92	(0.79,3.79)	2.90	(1.85,4.30)	0.86	(0.46,1.14)	2.40	(1.73,3.00)
RT5 – NS + UDI	1.92	(0.75,3.86)	2.88	(1.83,4.30)	0.86	(0.44,1.14)	2.37	(1.69,3.00)

Table 2: Key **catch-related** performance statistics for the RC and five robustness tests. CAV is the average TAC over the 10 (or 20) years. C(lowest) is the minimum TAC in the 10 (or 20) projection period and AAV is the average annual catch variation, calculated as the average of $(|C_{y+1} - C_y|)/C_y$ for $2027 \leq y \leq 2036$ and $2027 \leq y \leq 2046$

10-year	CAV		C(lowest)		AAV (2027-2036)	
RC	151	(125,159)	136	(108,152)	0.03	(0.01,0.05)
RT1 - No surveys	148	(122,157)	132	(105,145)	0.03	(0.01,0.06)
RT2 - All Industry	151	(125,159)	136	(109,152)	0.03	(0.01,0.06)
RT3 – Every 2nd year	151	(123,158)	137	(106,147)	0.03	(0.01,0.07)
RT4 – UDI	153	(128,159)	137	(112,152)	0.02	(0.01,0.05)
RT5 – NS + UDI	152	(128,158)	136	(111,146)	0.03	(0.01,0.06)
20-year	CAV		C(lowest)		AAV (2027-2046)	
RC	153	(137,159)	132	(105,148)	0.02	(0.01,0.04)
RT1 - No surveys	151	(133,158)	127	(98,144)	0.03	(0.01,0.05)
RT2 - All Industry	153	(137,159)	132	(106,149)	0.02	(0.01,0.05)
RT3 – Every 2nd year	153	(135,159)	132	(101,146)	0.02	(0.01,0.05)
RT4 – UDI	156	(140,160)	137	(111,152)	0.01	(0.00,0.04)
RT5 – NS + UDI	155	(139,159)	135	(107,146)	0.02	(0.01,0.04)

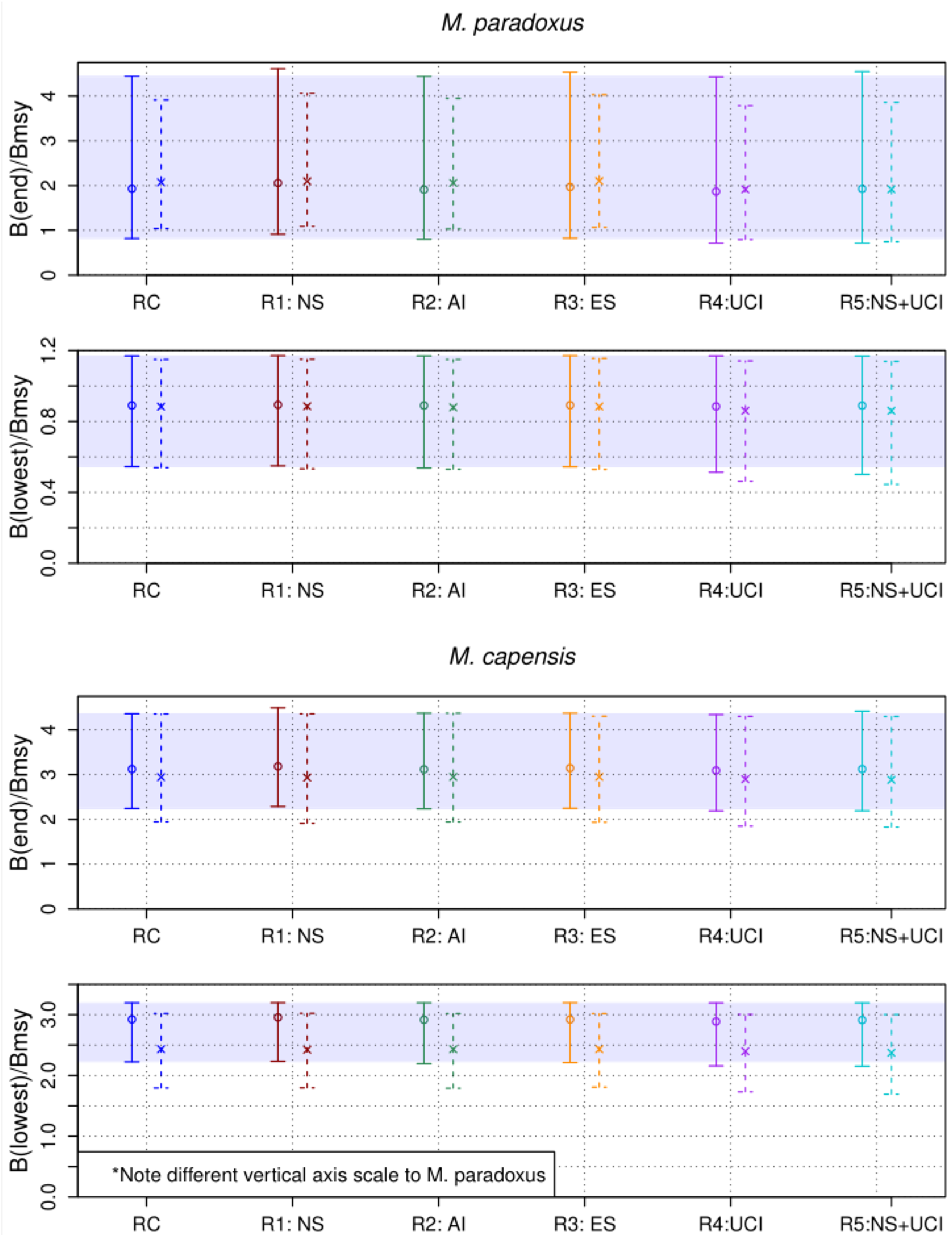

Figure 1a: Zeh plot of the **biomass-related** key performance statistics in Table 1, showing medians and 90% PIs. Open circles and solid lines have been used for the 10-year projections (i.e. $B(end) = 2036$) and the crosses and dashed lines for the 20 year projections (i.e. $B(end) = 2046$). The light blue shaded area shows the 90% PI for the RC (10-year projection) to aid comparison.

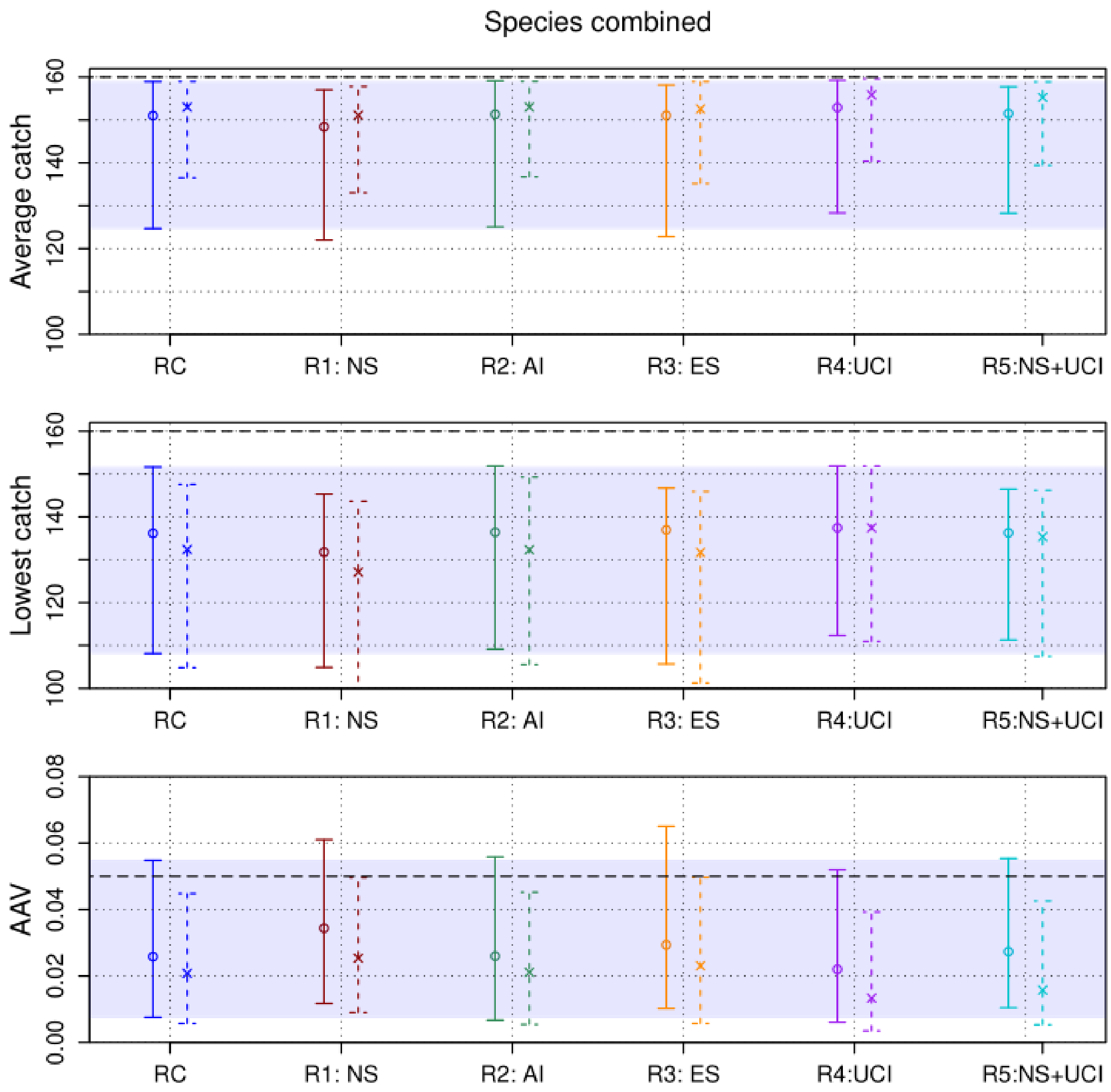

Figure 1b: Zeh plot of the **catch-related** key performance statistics in Table 2, showing medians and 90% PIs. Open circles and solid lines have been used for the 10-year projections and the crosses and dashed lines for the 20 year projections. The light blue shaded area shows the 90% PI for the RC (10 year projections) to aid comparison. Catch is in thousand tons. Note that the vertical axis for the top two plots starts from 100kt.

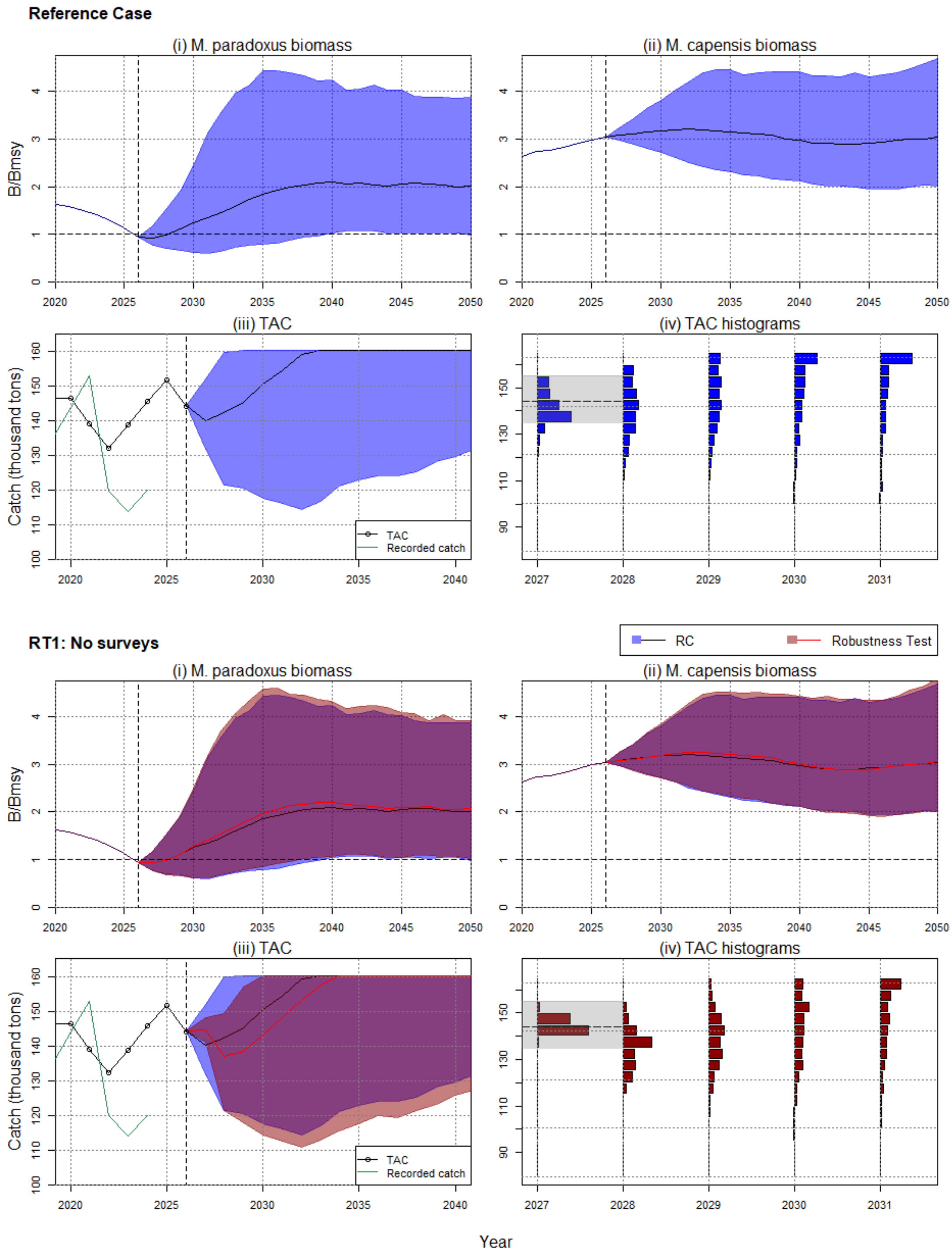

Figure 2a: The top four plots show the **RC** population trajectories for the two species (top row) and TAC trajectory and histograms of the projected TAC values for the next five years (second row). For the trajectories, medians and 90% PEs are shown. For the TAC trajectory plots, the actual recorded catches are shown by the green line. For the catch histograms, the 2026 TAC is marked by a dashed line, and the interval $TAC_{2026} \pm 5\%$ is shown by the grey shaded area. The TAC going outside this grey shaded area in 2027 is as a result of the *M. paradoxus J* index going below the threshold (see the Appendix). The bottom four plots compare these RC results with those for **RT1**, which assumes that no future surveys take place.

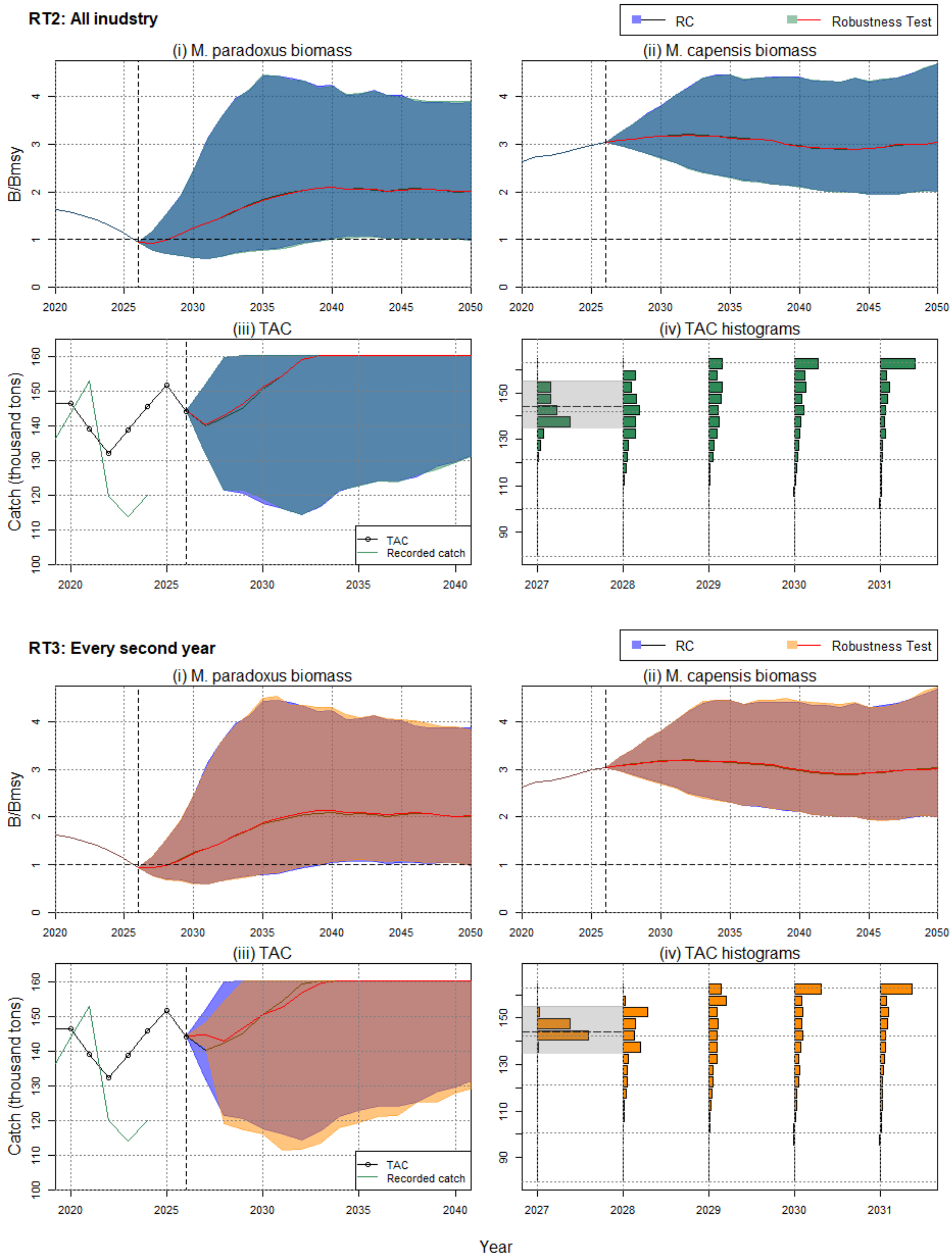

Figure 2b: Repeat of Figure 2a, but comparing **RT2** (all future surveys with industry vessel) with the RC (top four plots) and **RT3** (surveys take place every second year) with the RC (bottom four plots).

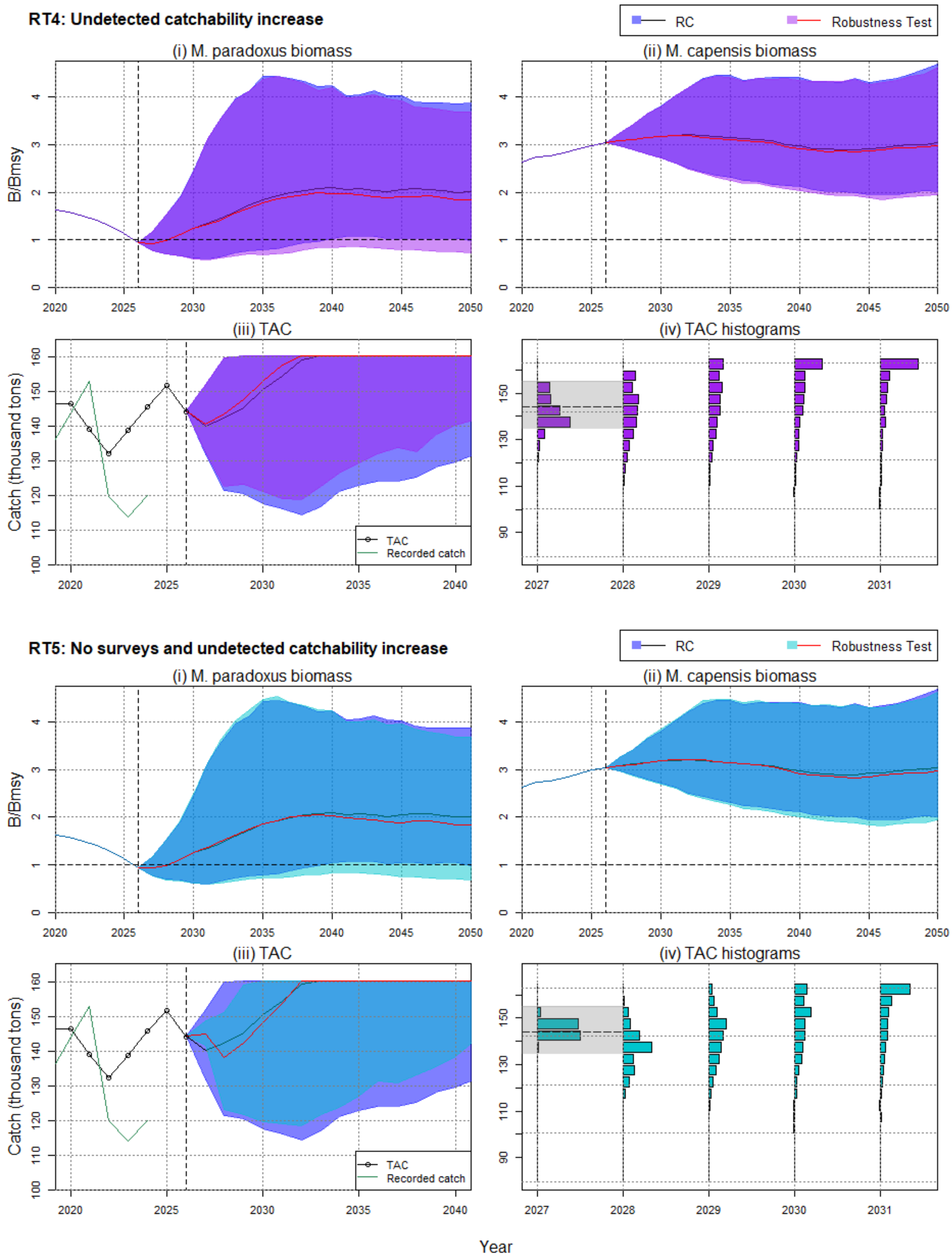

Figure 2c: Repeat of Figure 2a, but comparing **RT4** (undetected catchability increase) with the RC (top four plots) and **RT5** (undetected catchability increase with no future surveys) with the RC (bottom four plots).

Appendix – OMP2022 formula

The formula for computing the TAC recommendation under OMP-2022 is as follows:

$$TAC_{y+1} = C_{y+1}^{para} + C_{y+1}^{cap} \qquad \text{(A1)}$$

with

$$C_{y+1}^{spp} = b^{spp}\left(J_y^{spp} - J_0^{spp}\right) \qquad \text{(A2)}$$

where

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

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

J_0^{spp} and b^{spp} are tuning parameters (see Table 1), and

J_y^{spp} is a measure of the immediate past level in the abundance indices for species *spp* that is available to use for calculations for year *y.*

J_y^{spp} for the abundance indices is computed as follows:

$$J_y^{par} = \frac{1.0J_y^{WC\_CPUE,par} + 0.75J_y^{SC\_CPUE,par} + 0.5\left(\frac{n_{WC\_surv}}{3}\right)J_y^{WC\_surv,par} + 0.25\left(\frac{n_{SC\_surv}}{3}\right)J_y^{SC\_surv,par}}{1 + 0.75 + 0.5\left(\frac{n_{WC\_surv}}{3}\right) + 0.25\left(\frac{n_{SC\_surv}}{3}\right)} \qquad \text{(A3)}$$

$$J_y^{cap} = \frac{1.0J_y^{WC\_CPUE,cap} + 0.75J_y^{SC\_CPUE,cap} + 0.5\left(\frac{n_{WC\_surv}}{3}\right)J_y^{WC\_surv,cap} + 1.0\left(\frac{n_{SC\_surv}}{3}\right)J_y^{SC\_surv,cap}}{1 + 0.75 + 0.5\left(\frac{n_{WC\_surv}}{3}\right) + 1.0\left(\frac{n_{SC\_surv}}{3}\right)} \qquad \text{(A4)}$$

with

$$J_y^{WC/SC\_CPUE,spp} = \sum_{y'=y-3}^{y-1}\left(\frac{1}{3}\right)I_y^{WC/SC\_CPUE,spp} \Bigg/ \sum_{y=2011}^{2020}\left(\frac{1}{10}\right)I_y^{WC/SC\_CPUE,spp} \qquad \text{(A5)}$$

$$J_y^{WC/SC\_surv,spp} = \sum_{y'=y-2}^{y}\left(\frac{1}{3}\right)I_y^{WC/SC\_surv,spp} \Bigg/ \sum_{y=2012}^{2021}\left(\frac{1}{10}\right)I_y^{WC/SC\_surv,spp} \qquad \text{(A6)}$$

Maximum allowable annual change

The maximum allowable annual increase in TAC is 5%, and the maximum allowable annual decrease in TAC is 5% unless the *M. paradoxus* average biomass index falls too low, in which case the maximum allowable annual decrease becomes:

$$MaxDecr_y = \begin{cases} 5\% & \text{if } J_y \geq J^{thresh1} \\ \text{linear between x\% and 5\%} & \text{if } J^{thresh2} \leq J_y < J^{thresh1} \\ \text{x\%} & \text{if } J_y < J^{thresh2} \end{cases} \qquad \text{(A7)}$$

x, $J^{thresh1}$ and $J^{thresh1}$ are tuning parameters (see Table 1).

Upper cap and fixed TAC

Two further rules are included in OMP-2022:

i. An upper cap on the TAC is imposed, so that the TAC cannot exceed 160 000t.

ii. The TAC for 2023 is fixed at 138 760 tons (a 5% increase of the 2022 TAC). The TAC for 2024 is at least 138 760 tons, i.e., the 2024 TAC may be above the 2023 TAC, but may not be reduced below the 2023 TAC.