Initial OMP candidates for the Inaccessible and Gough rock lobster fisheries

S.J. Johnston and D.S. Butterworth

MARAM

Department of Mathematics and Applied Mathematics

University of Cape Town

Summary

Updated stock assessments for both Inaccessible and Gough have recently been reported. Inaccessible results assuming *M* = 0.2 (the reference case) are reported in the Appendix. Results for a number of candidate OMPs for the Inaccessible and Gough rock lobster fisheries are presented. Management targets are linked to future catch rates. For Inaccessible, CMP3+metarule2 is recommended as a reasonable OMP to be used to set the TAC from 2014. This OMP has a catch rate target of 4.0 kg/trap/day. CMP20+metarule1 is recommended similarly as appropriate for Gough. This OMP has a final catch rate target of 2.8 kg/trap/day. Both these recommended OMPs have a baseline inter-annual TAC change constraint of 5%, but both also have rules which will override this constraint if conditions in the fishery decline more than predicted. The predicted TAC trend for Inaccessible under CMP3+metarule2 is an increase in TAC annually of 5% in the future. For Gough, an increase in TAC of 5% is predicted under CMP20+metarule1 for the first few years, with the possibility that the TAC may decline somewhat after this, but remain near the 100 MT level into the future.

Introduction

In 2013, an OMP (Operational Management Procedure) was developed for the Tristan island rock lobster fishery (Johnston and Butterworth 2013). This OMP was used to set the quota at Tristan for the 2013 season, and will be used for the next three Seasons, with four yearly revisions thereafter. This document reports CMPs (Candidate Management Procedures) for the Inaccessible and Gough rock lobster fisheries, with the intention that the final selected OMP for each island will be used for setting the quotas at these two islands for the 2014 season and the following three seasons.

The stock assessment of the rock lobster populations at Inaccessible and Gough have both recently been updated (Johnston and Butterworth 2014). Both assessment models fit reasonably well to all available data (which include commercial CPUE and catch-at-length data, as well as data from the annual biomass surveys). The current spawning biomass (*Bsp*) relative to the pristine level (*K*) for both Inaccessible and Gough are both estimated to be at healthy values in the upper 80%'s. This suggests that these populations are well above the level at which maximum sustainable yields would be expected to be harvestable (usually a value of around 50% K or lower). As populations approach their carrying capacity (*K*), the productivity of the resource diminishes. For this reason, it is usually recommended that populations at high levels of spawning biomass relative to *K* can be more aggressively harvested to reduce their abundances to lower more productive levels.

As with the Tristan OMP, the management targets for these two islands are linked to the target catch rates which are considered to be the most desirable in the future. The ultimate aim of using an OMP to manage a resource is to try and reach such a management goal as closely as possible, no matter what eventuates in the future. If the resource declines in the future, this will be seen in the catch rates and TACs will be reduced, and more quickly should those rates fall below threshold levels. For the analyses that follow, TACs are constrained to not increase or decrease by any large amount between each season – here the baseline constraint is 5%. Rules that allow for a TAC decrease greater than 5% if catch rates decline appreciably are explored.

The impact that the OLIVA had on the resource at Inaccessible is modelled by assuming a 35% once off mortality of lobsters aged 1, 2 and 3 years during the 2011 season due to oil induced mortality. This was previously considered the most reasonable assumption[1]. Robustness of the CMPs' performance to this assumption is reported below.

It was recently realised that the Inaccessible assessment reported in Johnston and Butterworth (2014) assumed natural mortality M = 0.1. The intent was to in fact assume M = 0.2 (with the hope of reducing the need for domed shaped selectivity). Appendix 1 therefore reports an update to the Inaccessible RC assessment assuming M=0.2.This increase in M did not make much difference to the assessment results. A further assessment is also presented in the Appendix, robustness trail R1, for which the selectivity functions were all forced to be flat at larger sizes (i.e. domed selectivity was prevented) and time-invariant. The female growth parameter was estimated instead of being fixed at -15.0 as for the RC assessment. The rationale behind this robustness trial was to try to eliminate the need for "cryptic biomass" (substantial proportions of the largest lobsters present but not susceptible to harvesting). The resultant model fit for R1 shows similar goodness of fit to the CPUE data (see Table A1 last column), but the fit (in likelihood terms) to the observer CAL data diminishes quite substantially. Figure A2a

[1] Cape Town Workshop held 16-18 November 2011.

shows the R1 resultant average fit to the CAL data. In this Figure, the average fit to these data does not appear to be as "bad" as the poorer likelihood value suggests, indicating that while the RC model is still the "better" model with regards to the ability to fit to all the data, robustness trail R1 should be considered in CMP testing as a plausible alternative model. One large difference between the RC and the R1 assessment is that although both models estimate the Inaccessible resource to be currently > 80% *K*, the absolute values of the pre-exploitation spawning biomass *K* are very different: *K* = 1458 MT for the RC and 351 MT for R1, so that the current spawning biomass is also much smaller for R1. The RC allows for a large cryptic biomass due to the dome-shaped selectivity functions (which allow for better model fits to the CAL data). The robustness of OMP performance (in particular to the predicted spawning biomass trajectories) is tested for both the RC and R1; thus the final OMP recommendation made later in this document takes both these possible models into account.

Candidate OMPs (CMPs)

The CMPs presented here are based on the same structure as that for the Tristan OMP selected in 2013 (see Johnston and Butterworth 2013). This is a target-based rule based on the recent commercial CPUE, *viz.*

$$TAC_{y+1} = TAC_y + \alpha(I_y^{rec} - I^{tar}) \quad (1)$$

where

I_y^{rec} is the average of the GLM standardized CPUE over the last three years (*y*-2, *y*-1,*y*),

I^{tar} is the CPUE target index (the average GLM standardised 2010-2012

CPUE was used for Tristan), and

α is a tuning parameter which varies here from 2.5 to 10. The larger the α value, the more "responsive" the OMP will be to changes in the catch rate in the future.

A rule to control the inter-annual TAC variation is also applied. Unless otherwise stated, the % TAC change relative to the previous year is restricted to a maximum of either up 5% down 5%:

If $TAC_{y+1} < 0.95TAC_y$ then $TAC_{y+1} = 0.95TAC_y$

If $TAC_{y+1} > 1.05TAC_y$ then $TAC_{y+1} = 1.05TAC_y$

Results for CMPs that explore increasing this constraint to up/down to 10% are also reported. The addition of a precautionary metarule rule is also explored for both islands, where the 5% TAC decrease constraint is increased to up to 20% if the (catch rate) index drops below a threshold level.

Summary statistics

A number of summary statistics have been developed in order to compare the trade-offs and performances of the alternate CMPs. These are very similar to those used for the selection of the Tristan OMP.

- CR(2032) = catch rate expected in 2032 (in kg/gear/hour)
- CR(2022) = catch rate expected in 2022 (in kg/gear/hour)
- C_{ave} 10 = average annual catch (in MT) over the next 10 years (2014[2]-2023)
- V10 = average TAC change from the previous year over next 10 years (expressed as a %)
- The lower 5%ile of *Bsp*(2032)/*K* = the spawning biomass at the start of 2032 relative to the pristine level (*K*)

Each candidate CMP was run for 100 simulations. The medians, and the 5^{th} and 95^{th} percentiles of various management quantities of interest are reported.

Inaccessible CMPs

For Inaccessible, the average GLM standardised CPUE over 2010-2012 = **4.0.** CMPs that set I^{tar}=4.0 and 5.0 are explored here. Different values of α are also explored (the higher the α value, the more responsive the OMP can be to changes in CPUE). Results for the following four candidate CMPs are reported here:

CMP1: I^{tar}=4.0; α = 10; +5%, -5% maximum inter-annual TAC change constraint

CMP2: I^{tar}=4.0; α = 5; +5%, -5% maximum inter-annual TAC change constraint

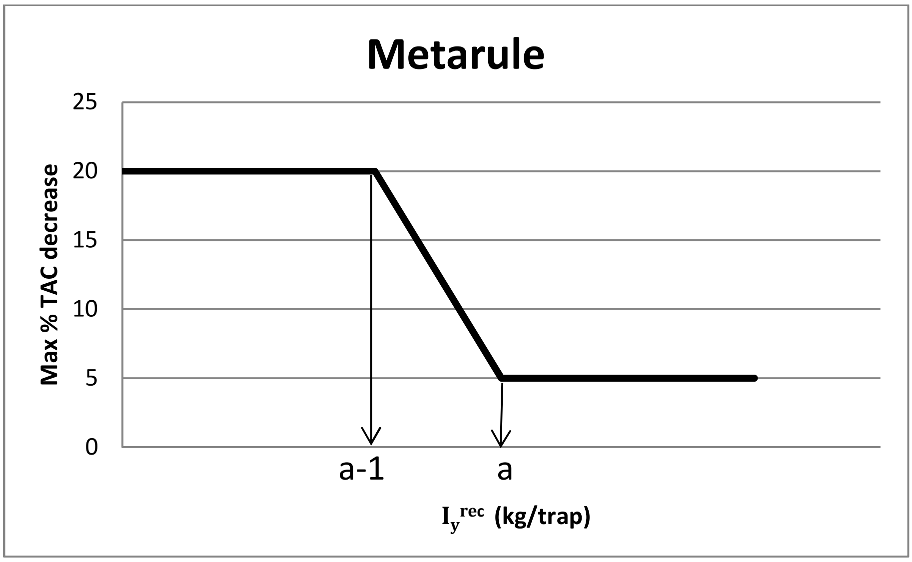
CMP3: I^{tar}=4.0; α = 2.5; +5%, -5% maximum inter-annual TAC change constraint

CMP4: I^{tar}=5.0; α = 10; +5%, -5% maximum inter-annual TAC change constraint

CMP4(10%): CMP4 but the maximum inter-annual TAC change constraint is increased to **10**% up and down.

Two further variants, "CMP4 + metarule1" and "CMP4 + metarule2", are identical to CMP4, except that they have a further "metarule" rule if the recent catch rate I_y^{rec} value drops below a threshold level. This metarule allows for the TAC to decrease further than the usual maximum 5% TAC decrease, as shown in the figure below:

[2] The split season is referred here by the first year, i.e. 2013 refers to 2013/14 season.



Two variants are reported here which vary w.r.t. the threshold level below which the metarule comes into play.

Metarule 1: a = **3** kg/trap

Metarule 2: a = **4** kg/trap

Thus for metarule 1, the amount by which the interannual TAC may decrease annually is allowed to alter (increase) for any values of I_y^{rec} less than 3 kg/trap, whereas for metarule 2, the metarule will kick in for I_y^{rec} values less than 4 kg/trap/

In order to test the effectiveness of the metarule, two robustness trials (R1 and R2) were developed as follows:

R1: This test assumes the selectivity functions are all "flat", i.e. does not allow for decreasing selectivity at larger sizes. The female growth parameter "t0" is also estimated in the model fit, not fixed at -15 as for the RC. [Comparisons between the RC and R1 are provided in Appendix 1].

R2: The extent of mortality on the juveniles in 2011 due to the OLVIA event is increased from 35% to 95%.

R3: The extent of mortality on juveniles in 2011 is increased to 95% for all ages 0-7. The future S-R relationship is modified for $Bsp(y)$< 1200 as follows:

$$R = \omega f_{BH}(B_{sp}) + (1-\omega)\frac{R_{1200}}{1200}B_{sp}$$

where $\omega = 0.3$. This means that at lower spawning biomasses, recruitment falls much more than would normally be expected.

R4: **R2, R3** and the assumption that 75% of all sized lobsters die in 2014 – once off mortality event.

Gough CMPs

For Gough, the average GLM standardised CPUE for 2010-2012 = **5.79.** CMPs that set I^{tar}=5.79, 5.0, 4.0, 3.5 and 3.0 were initially explored as well as different values of α. However, it was found, that allowing for a linear change in the I^{tar} value set over the first four years produced more stable TAC trajectories. The following candidate CMPs presented in this document are:

CMP16: I^{tar}=4.25 in 2014 decreasing linearly to 3.00 in 2017 and remaining 3.00 thereafter; α = 10; +5%, -5**%** maximum inter-annual TAC change constraint

CMP19: I^{tar}=4.50 in 2014 decreasing linearly to 3.00 in 2017 and remaining 3.00 thereafter; α = 10; +5%, -5**%** maximum inter-annual TAC change constraint

CMP20: I^{tar}=4.50 in 2014 decreasing linearly to 2.80 in 2017 and remaining 3.00 thereafter; α = 10; +5%, -5**%** maximum inter-annual TAC change constraint

CMP20(10%): CMP20 but the maximum inter-annual TAC change constraint is increased to **10**% up and down.

Two further variants, "CMP20 + metarule1" and "CMP20 + metarule2", are identical to CMP20, except that they have a further "metarule" rule if the recent catch rate I_y^{rec} value drops below a threshold level. This metarule allows for the TAC to decrease further than the usual maximum 5% TAC decrease, as shown in the figure above.

Two variants are reported here which vary w.r.t. the threshold level below which the metarule comes into play.

Metarule 1: a = **1.5** kg/trap

Metarule 2: a = **2.0** kg/trap

Thus for metarule 1, the amount by which the interannual TAC may decrease annually is allowed to alter (increase) for any values of I_y^{rec} less than 1.5 kg/trap, whereas for metarule 2, the metarule can kick in for I_y^{rec} values less than 2.0 kg/trap/

In order to test the effectiveness of the metarule, a robustness trial (R1) was developed for which 75% of all sized lobsters in 2014 are removed from the population (i.e. emigrate or die), i.e. a once off extreme event.

Results

Tables 1a and 2a report the expected performance results of the various CMPs explored for Inaccessible and Gough respectively for the "Reference Case" future scenario. All statistics reported are median values unless otherwise stated. Tables 1b – 1e report results for three CMPs for Inaccessible, for the robustness trials R1-R4. Table 2b reports results for Gough for the R1 robustness trial.

Figure 1 illustrates the expected median performance of TAC, CR (catch rate) and *Bsp* (spawning biomass) for the four CMPs explored for Inaccessible as well as a future constant catch of 70 MT. Figure 2 plots the median, 5th and 95thile trajectories for the Inaccessible CMP RC simulation results for CMP3 and CMP3+metarule2.

Figure 2b compares the median, 5th and 95th percentile TAC trajectories of CMP3 and CMP3(10%) at Inaccessible under, under the RC future scenario.

Figure 2c compares the median TAC, CR and *Bsp*/K trajectories for the robustness test R1 for Inaccessible – aimed at showing the utility of adding a metarule. Figures 2d, e and f are similar, but for the robustness tests R2, R3 and R4.

Similarly for Gough, Figure 3 illustrates the expected median performance of TAC, CR (catch rate) and *Bsp* (spawning biomass) for several of CMPs explored. The option of a future constant catch at 95 MT is also shown. Figure 4a plots the median, 5th and 95thile trajectories for the Gough CMP simulation results for CMP20 and CMP20 + metarule1 for the RC model. Figure 4b compares the median, 5th and 95th percentile TAC trajectories between CMP20 and CMP20(10%) – CMPs which differ only with respect to the value of the maximum interannual TAC constraint. Figures 5 and 6 and show similar plots, but these are for the robustness trial for which it is assumed that 75% of all lobsters die in 2014. The performance of CMP20 is compared with that of CMP20 + metarule 1 and CMP20 + metarule 2.

Finally, Figure 7 shows the trade-off between CR in 2022 against the average 10 year catch, Cave(10), for the different CMPs explored for both Inaccessible and Gough. The solid line shows a linear regression though the points on each plot. Note that several of the CMPs for which results are shown relate to earlier versions considered than those that have been explained in detail in this paper.

Discussion

There is a clear trade-off for both islands, between future catch rate (CR) and Catch. This can perhaps be seen most clearly in the plots shown in Figure 7. For both islands, the larger the average catch desired over the next 10 years, the lower the future catch rate is likely to be – both in 2022 and 2032.

Inaccessible

The average CR at Inaccessible over the 2010-2012 period was 4.0 kg/gear/hour. If the TAC remains at 70 MT, the CR is expected to increase to near 6 kg/gear/hour by 2022 (see Table 1a). There is clearly the possibility to increase the TAC safely to above 70 MT, in conjunction with a suitable CMP, whilst still maintaining the final spawning biomass (in 2033) at high levels relative to *K* (see Figure 1 bottom plot and Table 1a). Indications are that the CPUE for the 2013 season will be as good if not higher than the previous few seasons (see Johnston 2014). The question at this stage is what would a suitable target CPUE would be for Inaccessible? It is suggested that CMP3 (with Itar = 4.0) would be an appropriate choice for the OMP for this resource. This option would be more conservative than CMP1, and be associated with an expected median Cave(10) of around **84 MT**. The lower 5^{th} %ile for *Bsp*(2033)/*K* would also be above 0.5*K* (and a little higher than for CMP1 at a value of 0.56).

It is further suggested that a metarule2 be added, thus CMP3+metarule2 is the recommended CMP. The addition of this metarule means that if some unforeseen negative conditions occur in the future, the OMP will be able to react fast by reducing the TAC by more than the usual maximum 5% per season. If there is no "disaster" in the future (as suggested by the RC and R1, R2, R3 and R4), then the metarule will not be invoked. If however, as suggested by R4, a rapid decline in CPUE occurs, the OMP can adjust the TACs downwards to a greater degree until catch rates recover (see Figure 2e).

Gough

The average CR at Gough over the 2010-2012 period was 5.79 kg/trap. If the TAC remains at 95 MT, the CR is expected to decrease to just below 3 kg/trap by 2022 (see Table 2a and Figure 3). Variations in the median TAC trajectories are shown in Figure 3 for several CMPs. CMP20 provides a desirable TAC trajectory, with the median TAC staying between 95MT and 105 MT for most of the trajectory period. The advantage of these CMPs though (compared to setting constant catches) is that if future CRs are lower than current values, the TAC will be reduced, and *vice versa*. Figure 4a shows not only the median expected TACs and catch rates, but also the 90% probability envelopes. These indicate that there is a 90% certainty that future TACs and CRs will fall between the dotted ranges illustrated.

Figure 4b shows that increasing the maximum interannual TAC change constraint from 5% to 10% has little effect on the results in median terms, but the 5^{th} and 95^{th} percentiles of the TAC trajectories under the CMP20(10%) are much wider – particularly in the later years of the trajectory period.

CMP20 + metarule1 (or metarule2), provides the extra assurance that if CRs do suddenly start dropping (below either 2.0 or 1.5 kg/trap in terms of the 3-year average), then the OMP will allow for the TAC to drop by as much as 20% per year if required. These results show that adding the metarule (1 or 2) to the Gough OMP will make virtually no difference for the expected future conditions under the RC, but if a future negative conditions occur (as simulated in the robustness test R1), the metarule will allow for the TAC to be decreased beyond the normal 5% maximum per annum if the catch rates fall below the threshold levels.

As for Inaccessible, CMP20 on its own appears robust to the robustness trial explored here. If the catch rates drop rapidly, the TAC is brought down. The metarule allows for the TAC to be reduced faster, and thus for the resource to recover at a faster pace, as shown in Figure 5.

Management Recommendations

Inaccessible

CMP3 + metarule2 is recommended as a reasonable CMP to be used to set the TAC for the Inaccessible fishery from the 2014 season. This CMP is expected to produce a median average TAC over the next 10 years of around 84 MT. Clearly, if the resource behavior is more pessimistic than expected, this value would be lower (see Tables 1b and 1c). The median final spawning biomass in 2032 is expected to be around 0.94K. The addition of metarule2, which kicks in if the catch rate drops below 4 kg/tap is a further safeguard for the resource if something "bad" happens in the future. TACs will then be allowed to decrease fast enough to ensure resource recovery.

Gough

CMP20 + metarule 1 is recommended as a reasonable CMP to be used to set the TAC for the Gough lobster fishery from the 2014 season. This CMP produces a stable median TAC trajectory for the future, and is associated with an initial catch rate of 4.5 kg/trap and a final catch rate target of 2.8 kg/trap. The advantage of CMP20 + metarule 1 over the more simple CMP20, is that if in the future some unforeseen negative conditions strike the resource and causes the CPUE to drop sharply, the maximum interannual decrease constraint of 5% can be overridden, and a decrease in TAC of as much as 20% would be set if the metarule so indicated. The median final spawning biomass in 2032 is expected to be around 0.75K. This indicates that this CMP should not pose any risk of unduly depleting the spawning biomass of this resource. Metarule1 "kicks in" if the catch rate (average over three seasons) drops below 1.5 kg/trap. Whilst the catch rates at Gough have been very high in recent seasons, most likely due to extremely good recruitment, there are signs these catch rates will return to lower levels. The final target catch rate of 2.8 kg/day is considered a reasonable and safe management target, with the metarule1 coming into operation if catch rates drop below 1.5 kg/day.

References

Johnston, S.J. 2014. Comparative plots of commercial CPUE and biomass survey index data (Leg1) for the Tristan da Cunha group of islands. MARAM/TRISTAN/2014/MAR/05. 3pp.

Johnston, S.J. and Butterworth, D.S. 2013. An operational management procedure for the Tristan da Cunha rock lobster fishery. MARAM/TRISTAN/2013/OCT/14.

Johnston, S.J. and Butterworth, D.S. 2014. Updated 2014 Inaccessible and Gough island assessments. MARAM/TRISTAN/2014/JAN/02. 30pp.

Table 1a: Comparison of **Inaccessible** initial candidate OMPs **RC** expected performance results. All statistics reported below are median values unless otherwise stated. Values **bolded i**ndicate changes from CMP1 selections.

CMP	I^{tar}	α	Inter-annual maximum TAC constraint	CR(2022) (kg/trap)	CR(2032) (kg/trap)	C_{ave} 10 (MT)	Lower 5%ile C_{ave} 10	V10 (%)	Lower 5%ile *Bsp*(2033/K)
	CC = 70 MT		-	5.93	5.31	70	70	0	0.59
CMP1	4.0	10	+5%,-5%	5.50	4.20	91.93	85.99	4.87	0.55
CMP2	4.0	**5**	+5%,-5%	5.51	4.29	90.12	83.81	4.47	0.55
CMP3	4.0	**2.5**	+5%,-5%	5.61	4.50	84.46	78.20	3.43	0.56
CMP4	**5.0**	10	+5%,-5%	5.87	4.97	73.37	60.18	4.02	0.58
CMP3(10%)	4.0	**2.5**	+**10**%,-**10**%	5.61	4.49	85.50	78.20	3.64	0.56
CMP3+metarule 1	4.0	**2.5**	+5%,-5 to **-20**%	5.62	4.50	84.46	78.20	3.44	0.56
CMP3+metarule 2	4.0	**2.5**	+5%,-5 to **-20**%	5.62	4.51	84.46	78.20	3.44	0.56

Table 1b: Comparison of **Inaccessible** CMP3, CMP3+metarule1 and CMP3+metarule2 expected performance results for the robustness trial **R1** which assumes selectivity functions are "flat" at larger sizes, and estimates the female t0 growth parameter. All statistics reported below are median values unless otherwise stated.

CMP	I^{tar}	α	Inter-annual maximum TAC constraint	CR(2022) (kg/trap)	CR(2032) (kg/trap)	C_{ave} 10 (MT)	Lower 5%ile C_{ave} 10	V10 (%)	Lower 5%ile *Bsp*(2033/K)
CMP3	**4.0**	2.5	+5%,-5%	5.47	4.17	81.92	75.67	2.93	0.57
CMP3+metarule1	**4.0**	2.5	+5%,-5 to **-20**%	5.47	4.24	81.92	75.67	2.93	0.57
CMP3+metarule2	**4.0**	2.5	+5%,-5 to **-20**%	5.47	4.25	81.92	75.67	2.93	0.57

Table 1c: Comparison of **Inaccessible** CMP3, CMP3+metarule1 and CMP3+metarule2 expected performance results for the robustness trial **R2** which assumes the oil effect following the OLIVA incident is greater than assumed for the RC, and that 95% of all lobsters aged 1-3 die in 2011. All statistics reported below are median values unless otherwise stated.

CMP	I^{tar}	α	Inter-annual maximum TAC constraint	CR(2022) (kg/trap)	CR(2032) (kg/trap)	C_{ave} 10 (MT)	Lower 5%ile C_{ave} 10	V10 (%)	Lower 5%ile *Bsp*(2033/K)
CMP3	**4.0**	2.5	+5%,-5%	5.95	4.92	68.52	63.15	2.56	0.57
CMP3+metarule1	**4.0**	2.5	+5%,-5 to **-20**%	5.95	4.96	67.74	59.40	3.02	0.57
CMP3+metarule2	**4.0**	2.5	+5%,-5 to **-20**%	6.00	4.96	67.74	53.08	3.11	0.57

Table 1d: Comparison of **Inaccessible** CMP3, CMP3+metarule1 and CMP3+metarule2 expected performance results for the robustness trial **R3** – 95% of all 0-7 aged lobsters fie in 2011, and the future S-R relationship is modified (see text). All statistics reported below are median values unless otherwise stated.

CMP	I^{tar}	α	Inter-annual maximum TAC constraint	CR(2022) (kg/trap)	CR(2032) (kg/trap)	C_{ave} 10 (MT)	Lower 5%ile C_{ave} 10	V10 (%)	Lower 5%ile *Bsp*(2033/K)
CMP3	**4.0**	2.5	+5%,-5%	3.33	5.09	57.33	54.61	4.58	0.52
CMP3+metarule1	**4.0**	2.5	+5%,-5 to **-20**%	3.95	5.73	36.02	31.96	11.44	0.54
CMP3+metarule2	**4.0**	2.5	+5%,-5 to **-20**%	3.95	5.84	34.49	30.57	13.08	0.55

Table 1e: Comparison of **Inaccessible** CMP3, CMP3+metarule1 and CMP3+metarule2 expected performance results for the robustness trial **R4 (R2, R3 and 75% of all lobster die in 2014)**. All statistics reported below are median values unless otherwise stated.

CMP	I^{tar}	α	Inter-annual maximum TAC constraint	CR(2022) (kg/trap)	CR(2032) (kg/trap)	C_{ave} 10 (MT)	Lower 5%ile C_{ave} 10	V10 (%)	Lower 5%ile *Bsp*(2033/K)
CMP3	**4.0**	2.5	+5%,-5%	2.27	5.23	58.52	57.18	4.36	0.61
CMP3+metarule1	**4.0**	2.5	+5%,-5 to **-20**%	2.85	5.75	37.28	36.45	16.04	0.63
CMP3+metarule2	**4.0**	2.5	+5%,-5 to **-20**%	2.85	5.78	37.20	36.38	16.36	0.64

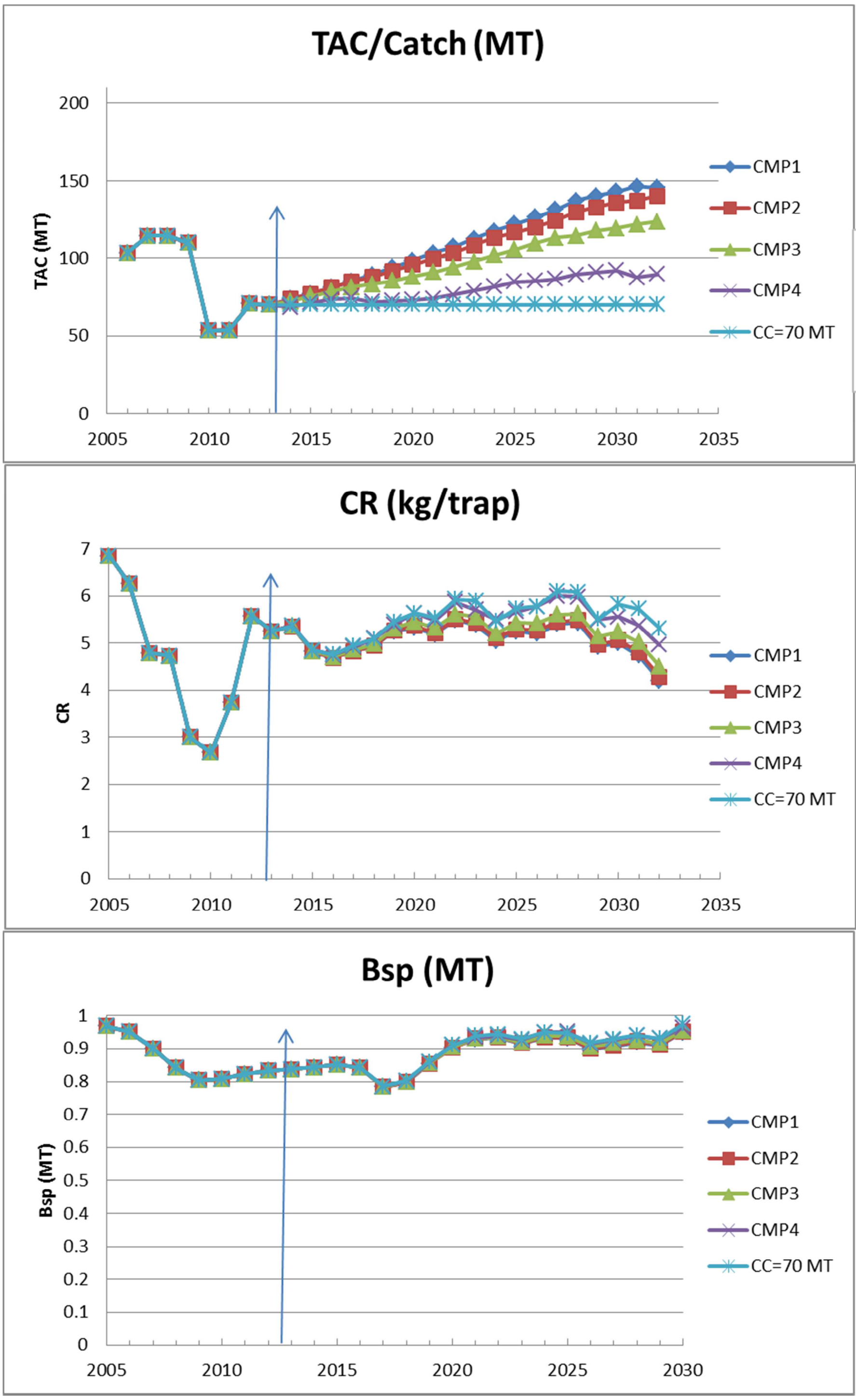
Table 2a: Comparison of **Gough** initial candidate OMPs **RC** expected performance results. All statistics reported below are median values unless otherwise stated.

CMP	I^{tar}	α	Inter-annual maximum TAC constraint	CR(2022) (kg/trap)	CR(2032) (kg/trap)	C_{ave} 10 (MT)	Lower 5%ile C_{ave} 10	V10 (%)	Lower 5%ile *Bsp*(2033/K)
	CC = 95 MT		-	2.89	2.68	95	95	0	0.39
CMP12	**3.0**	**5**	+5%,-5%	2.52	2.58	105	100	2.71	0.39
CMP16	**4.25-3.0**	10	+5%,-5%	2.83	2.64	98.27	88.21	3.22	0.39
CMP19	**4.50-3.00**	10	+5%,-5%	2.87	2.63	96.03	86.27	3.15	0.39
CMP20	**4.50-2.80**	10	+5%,-5%	2.71	2.41	100.44	90.22	3.19	0.39
CMP20(10%)	**4.50-2.80**	10	+**10**%,-**10**%	2.67	2.78	103.00	90.51	4.16	0.39
CMP20+ metarule1	**4.50-2.80**	10	+5%,-5 to **-20**%	2.71	2.47	100.44	90.22	3.19	0.39
CMP20+ metarule2	**4.50-2.80**	10	+5%,-5 to **-20**%	2.71	2.73	100.44	90.00	3.24	0.40

Table 2b: Comparison of **Gough** CMP20, CMP20+metarule1 and CMP20+metarule2 expected performance results for the robustness trial **R1** which assumes 75% of all lobsters are removed from the population during 2014. All statistics reported below are median values unless otherwise stated. Values **bolded** indicate changes from CMP1 selections.

CMP	I^{tar}	α	Inter-annual maximum TAC constraint	CR(2022) (kg/trap)	CR(2032) (kg/trap)	C_{ave} 10 (MT)	Lower 5%ile C_{ave} 10	V10 (%)	Lower 5%ile *Bsp*(2033/K)
CMP20	**4.50-2.80**	10	+5%,-5%	1.91	3.52	80.05	80.05	5.00	0.43
CMP20+ metarule1	**4.50-2.80**	10	+5%,-5 to **-20**%	2.38	4.33	60.91	59.09	11.52	0.49
CMP20+ metarule2	**4.50-2.80**	10	+5%,-5 to **-20**%	2.51	4.67	56.47	54.64	14.17	0.51

Figure 1: Preliminary **Inaccessible RC** CMP simulation results. Median trajectories of four CMPs are shown. Vertical arrows show the start of the projection period. In the *Bsp* plot the horizontal dashed red line indicates the estimated *K* (unexploited spawning biomass level).



CMP1 = Itarg = 4.0; α=10; IACC=5%
CMP2 = Itarg = 4.0; α=**5**; IACC=5%
CMP3 = Itarg = 4.0; α=**2.5**; IACC=5%
CMP4 = Itarg = **5.0**; α=10; IACC=5%

Figure 2a: Preliminary **Inaccessible RC** CMP simulation results for CMP3 (Itarg=4.0; α=2.5; IACC=5%) and CMP3+metarule2. Median, 5th and 95th percentile trajectories are shown. Vertical arrows show the start of the projection period.

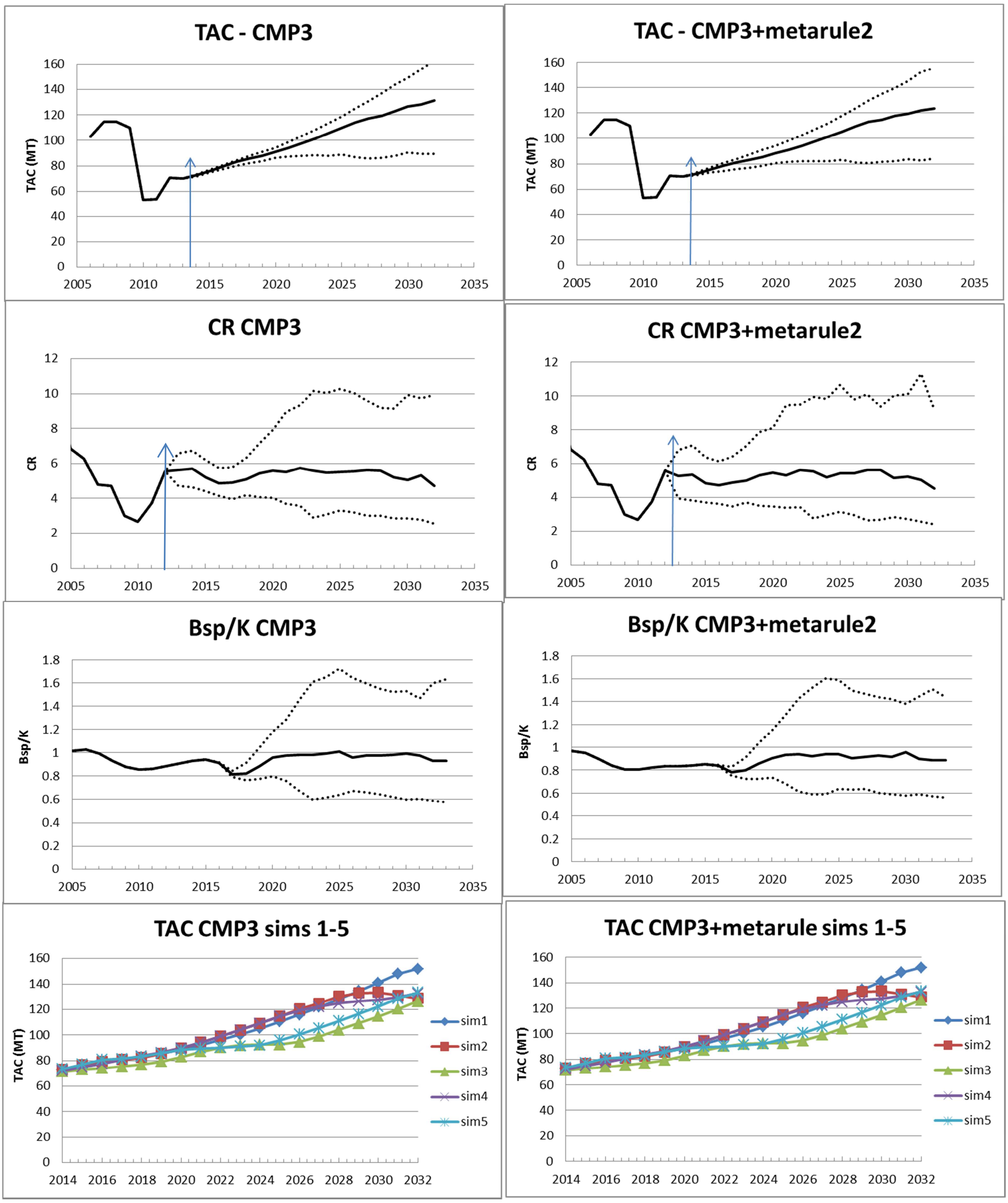


Figure 2b: A comparative plot of **Inaccessible CMP3** and **CMP3(10%)** showing median, 5th and 95th percentiles of expected TAC trajectories (under RC future assumptions). The **black** lines show CMP3 (with a **5**% maximum interannual TAC change constraint) and the **grey** lines show CMP3(10%) which has **10**% maximum interannual TAC change constraint.

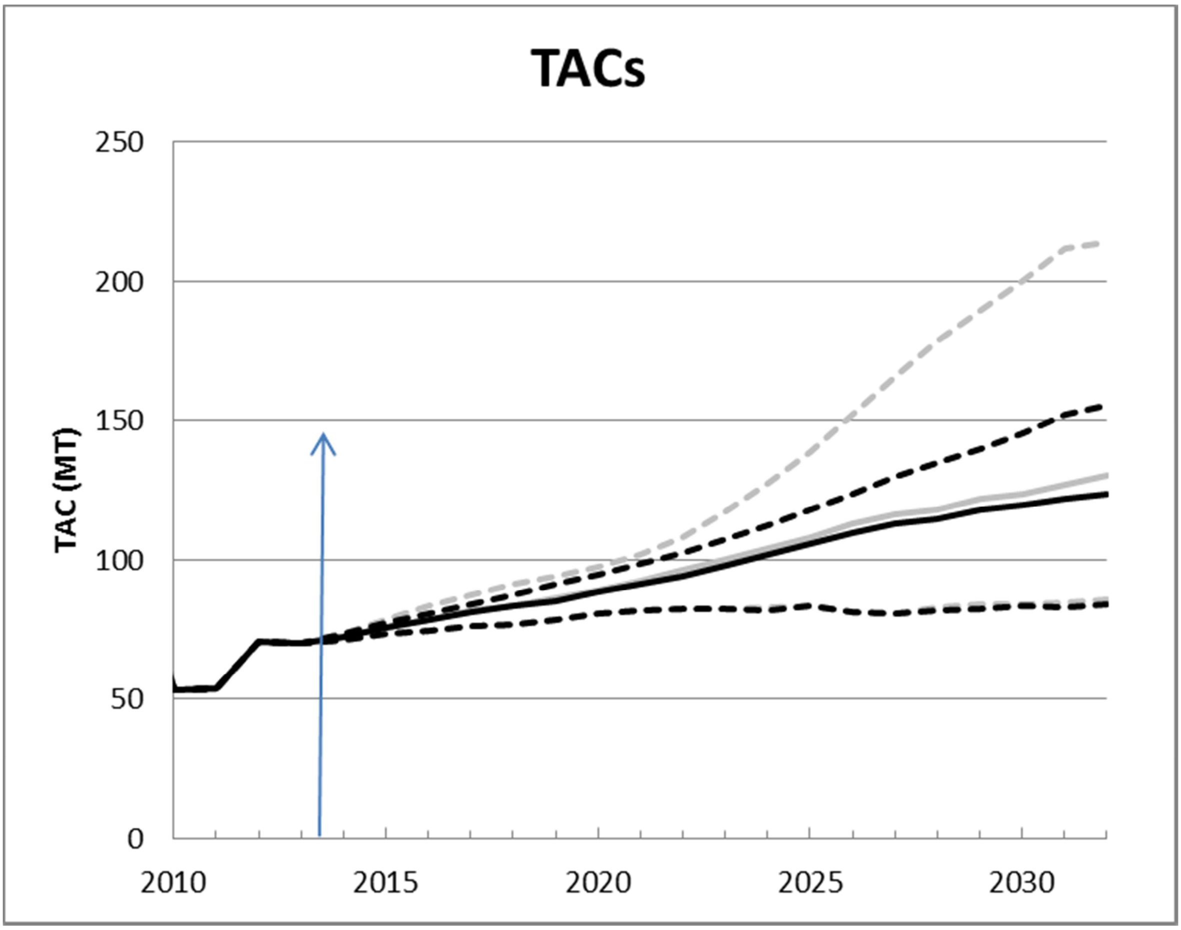


Figure 2c: **Inaccessible** CMP median trajectories for **CMP3**, **CMP3 + metarule1 and CMP4 + metarule 2 for the robustness test R1 which assumes selectivity functions are flat for larger sized lobsters, and female growth parameter t0 is estimated within the model fit**.

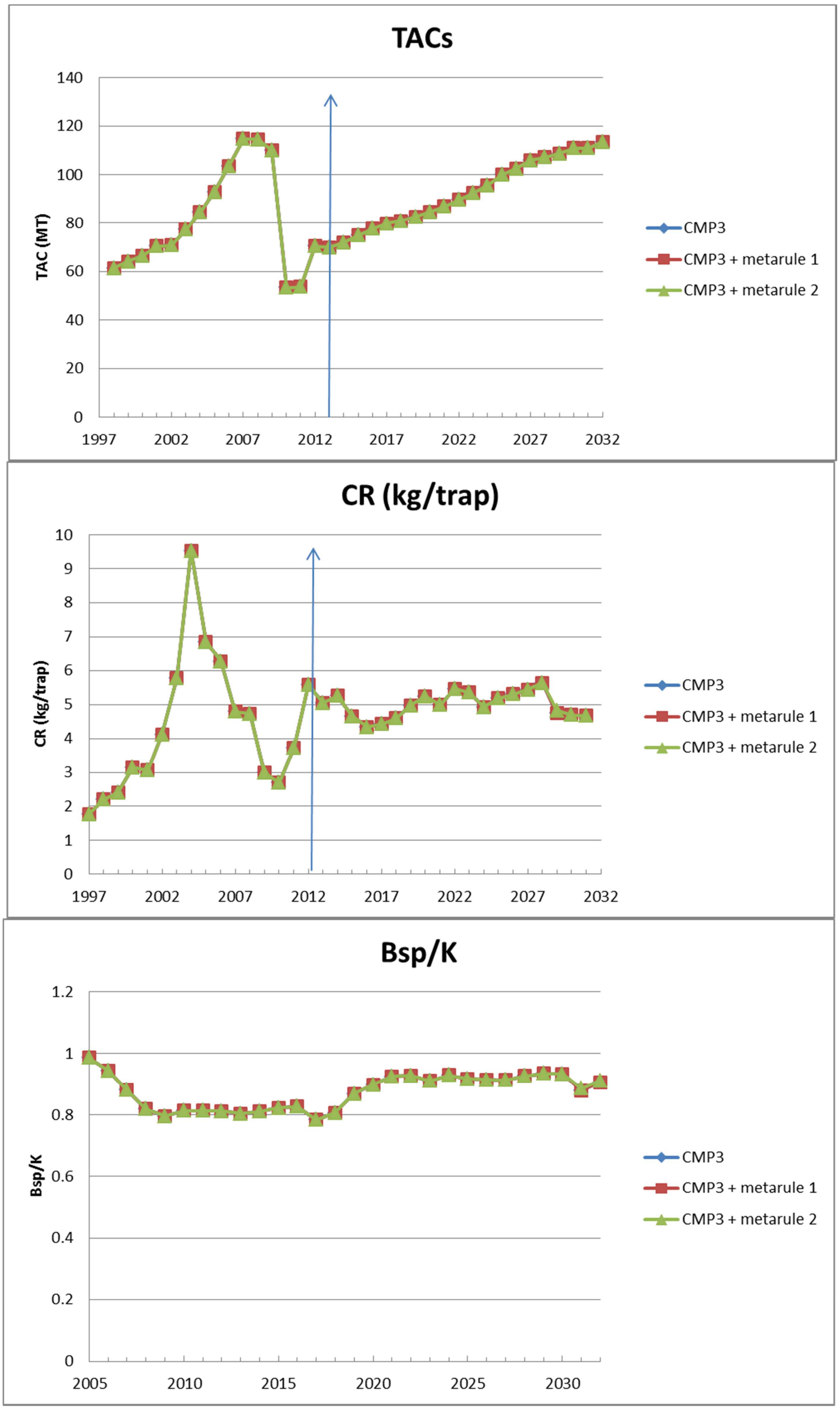


Figure 2d: **Inaccessible** CMP median trajectories for **CMP3**, **CMP3 + metarule1 and CMP3 + metarule 2 for the robustness test R2 which assumes 95% of juvenile lobsters die in 2011 due to the OLVIA event.**

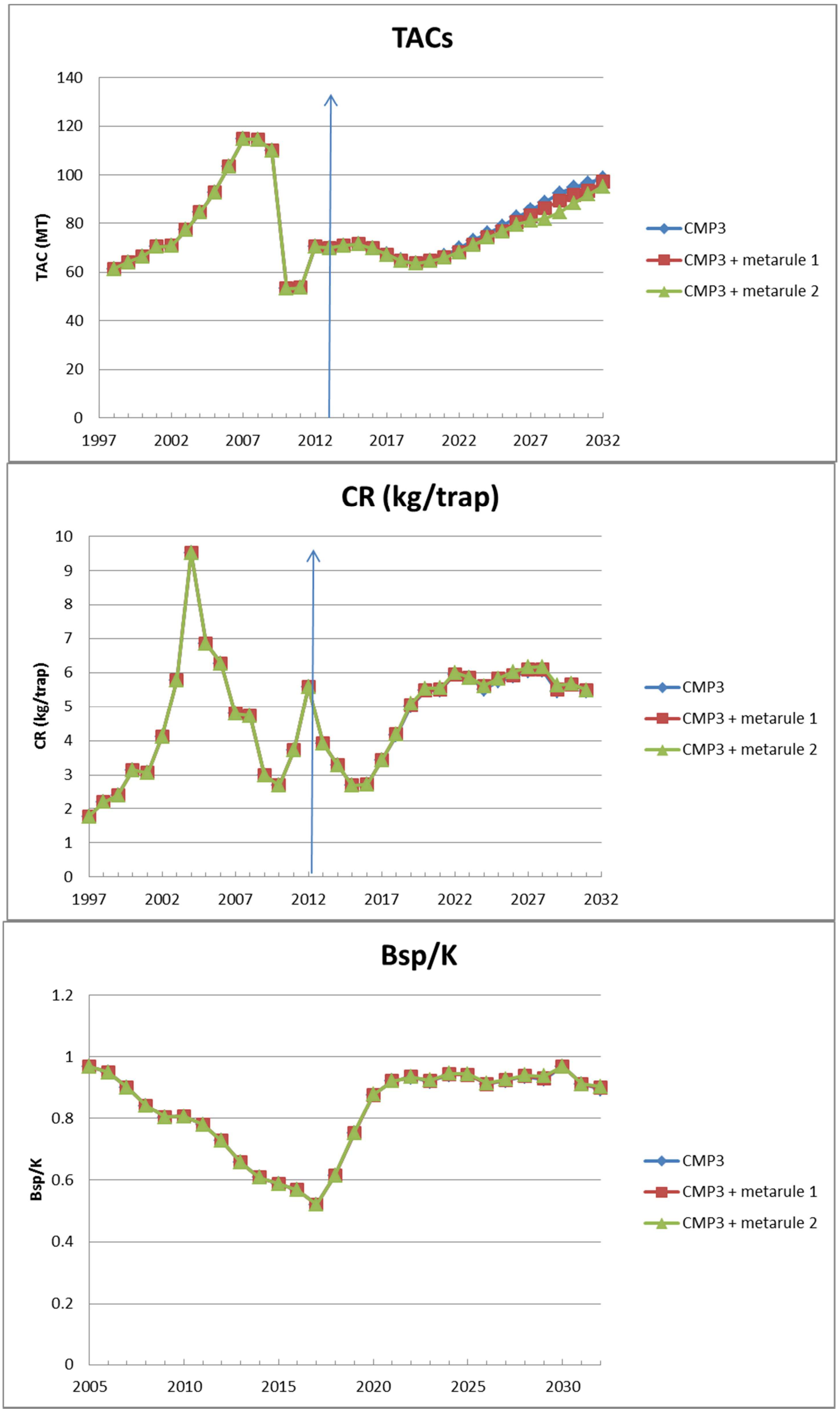


Figure 2e: **Inaccessible** CMP median trajectories for **CMP3**, **CMP3 + metarule1 and CMP3 + metarule 2 for the robustness test R3** (extent of mortality on juveniles in 2011 is increased to 95% for all ages 0-7 and the future S-R relationship is modified for $Bsp(y)$< 1200 **as described in the text).**

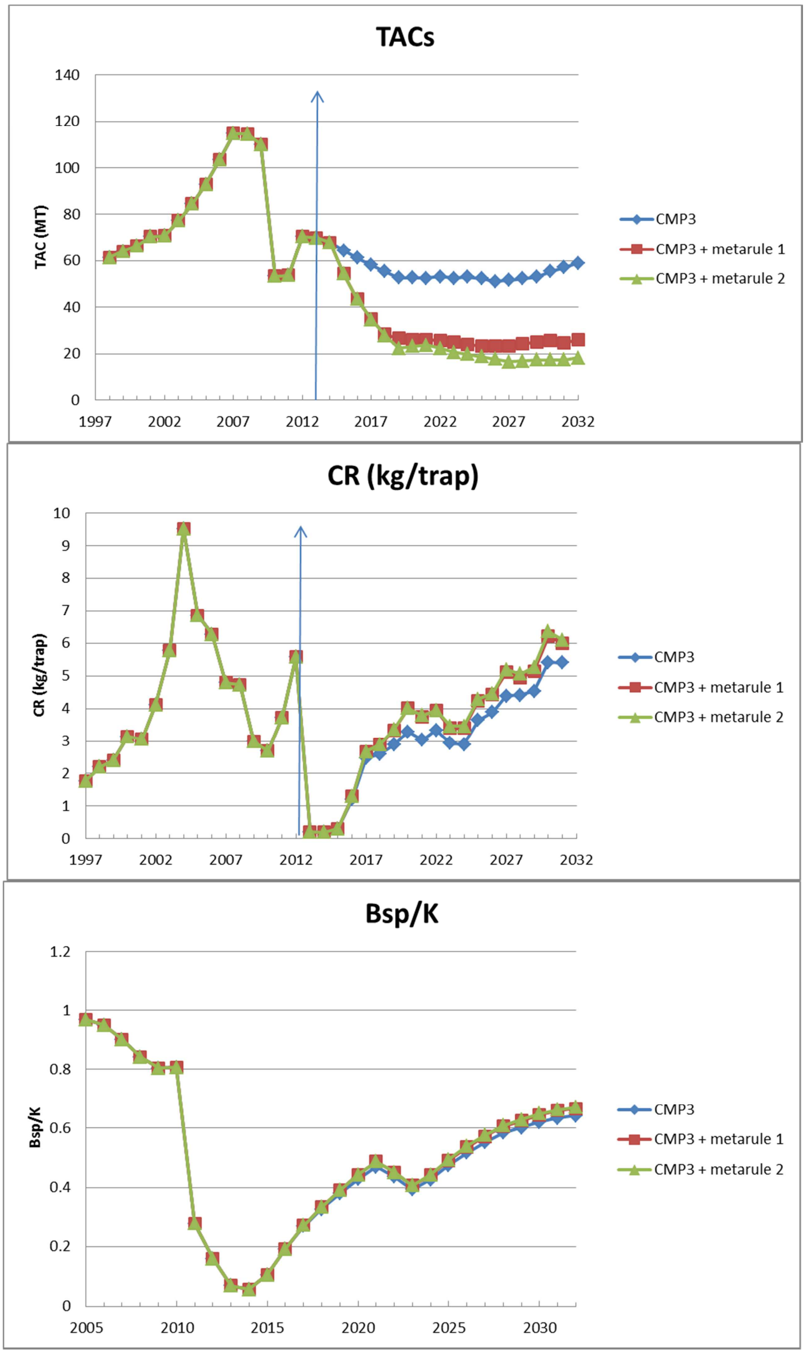


Figure 2f: **Inaccessible** CMP median trajectories for **CMP3**, **CMP3 + metarule1 and CMP3 + metarule 2 for the robustness test R4 (R2, R3** and the assumption that 75% of all sized lobsters die in 2014 – once off mortality event).

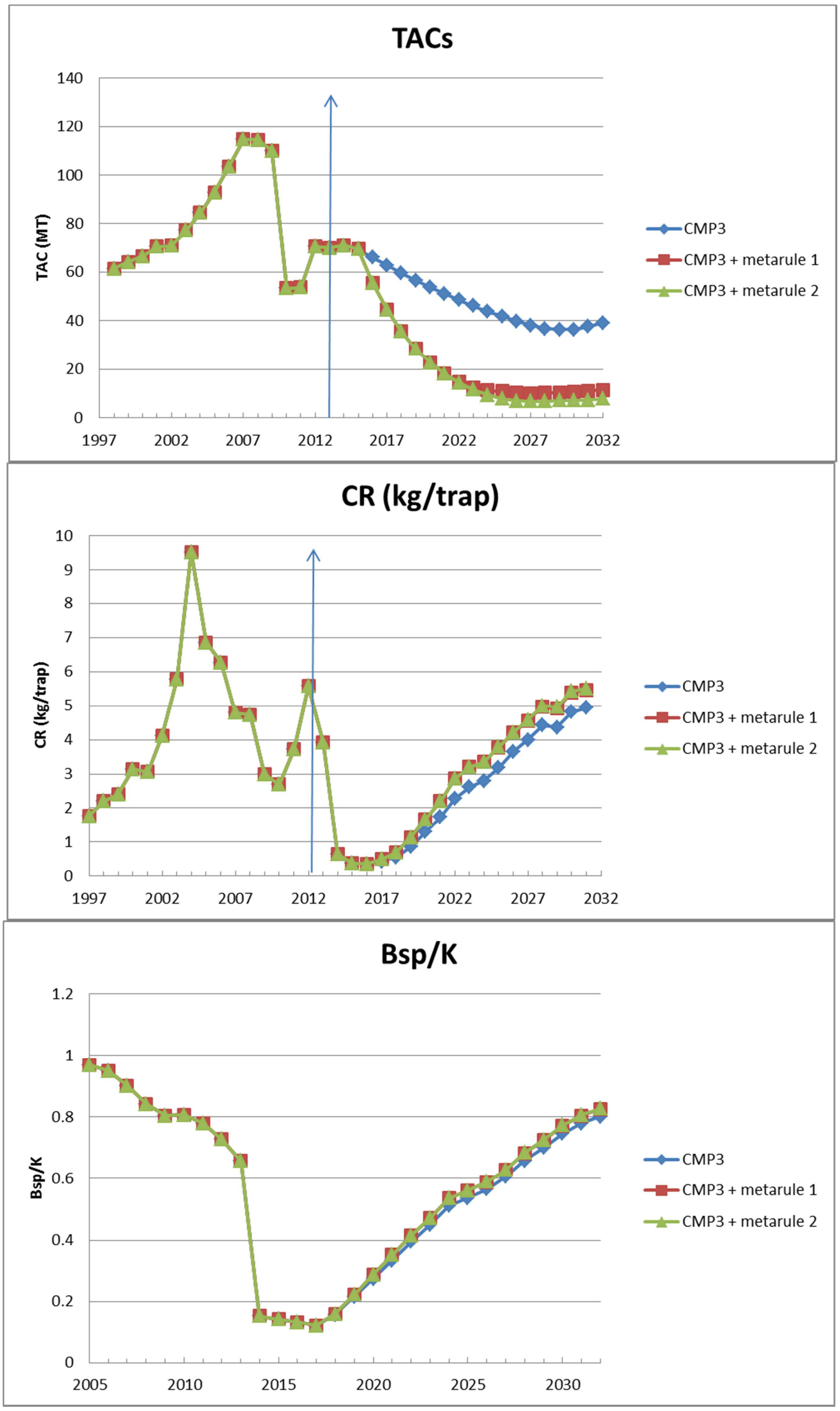
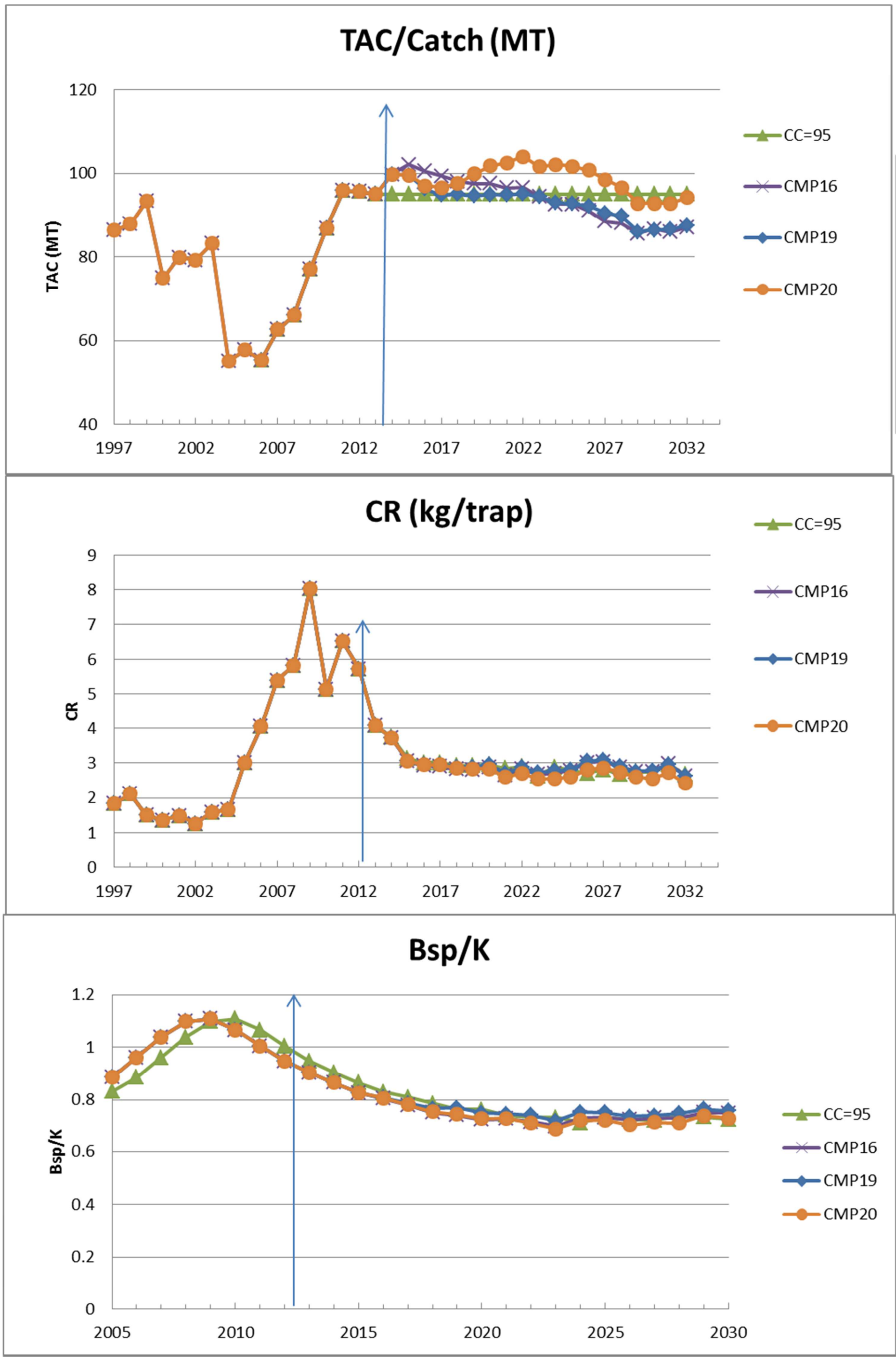


Figure 3: Preliminary **Gough** CMP **RC** simulation results. Median trajectories of four CMPs are shown. Vertical arrows show the start of the projection period. CMP20+metarule options are not shown on these plots, as they are virtually identical to the CMP20 RC results.



CC=95 (constant future catch of 95 MT)
CMP16= Itarg = 4.25-3.00 over first 4 years; α=10; IACC=**5%**
CMP19= Itarg = 4.50-3.00 over first 4 years; α=10; IACC=**5%**
CMP20= Itarg = 4.50-2.80 over first 4 years; α=10; IACC=**5%**

Figure 4a: Preliminary **Gough** CMP **RC** simulation results for **CMP20** and **CMP20 + metarule1**. Median, 5th and 95th percentile trajectories are shown. Vertical arrows show the start of the projection period.

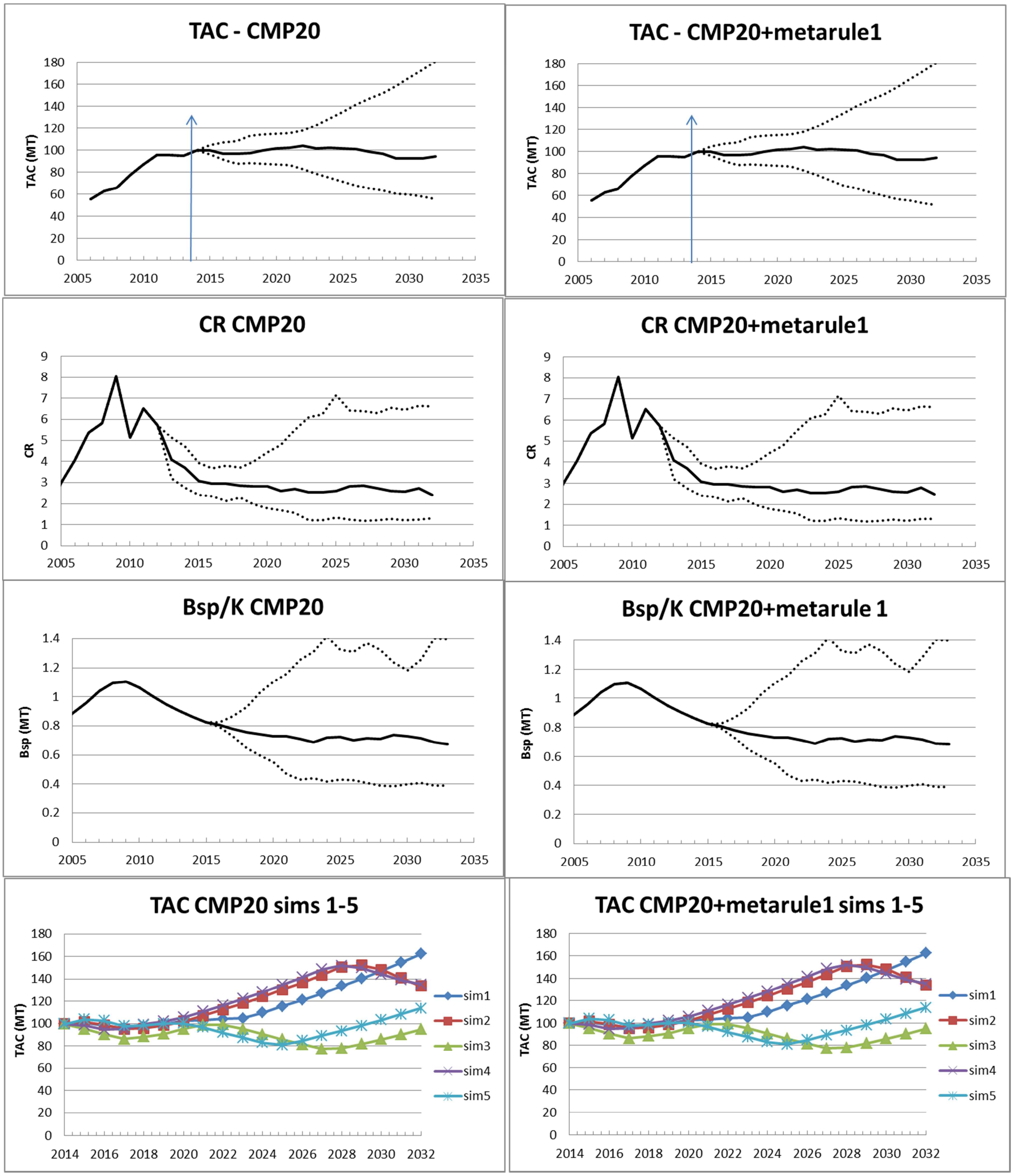


Figure 4b: A comparative plot of **Gough** CMP20 and CMP20(10%) showing median, 5th and 95th percentiles of expected TAC trajectories (under **RC** future assumptions). The **grey** lines show CMP20 (with a **5**% maximum interannual TAC change constraint) and the **black** lines show CMP20(10%) which has **10**% maximum interannual TAC change constraint.

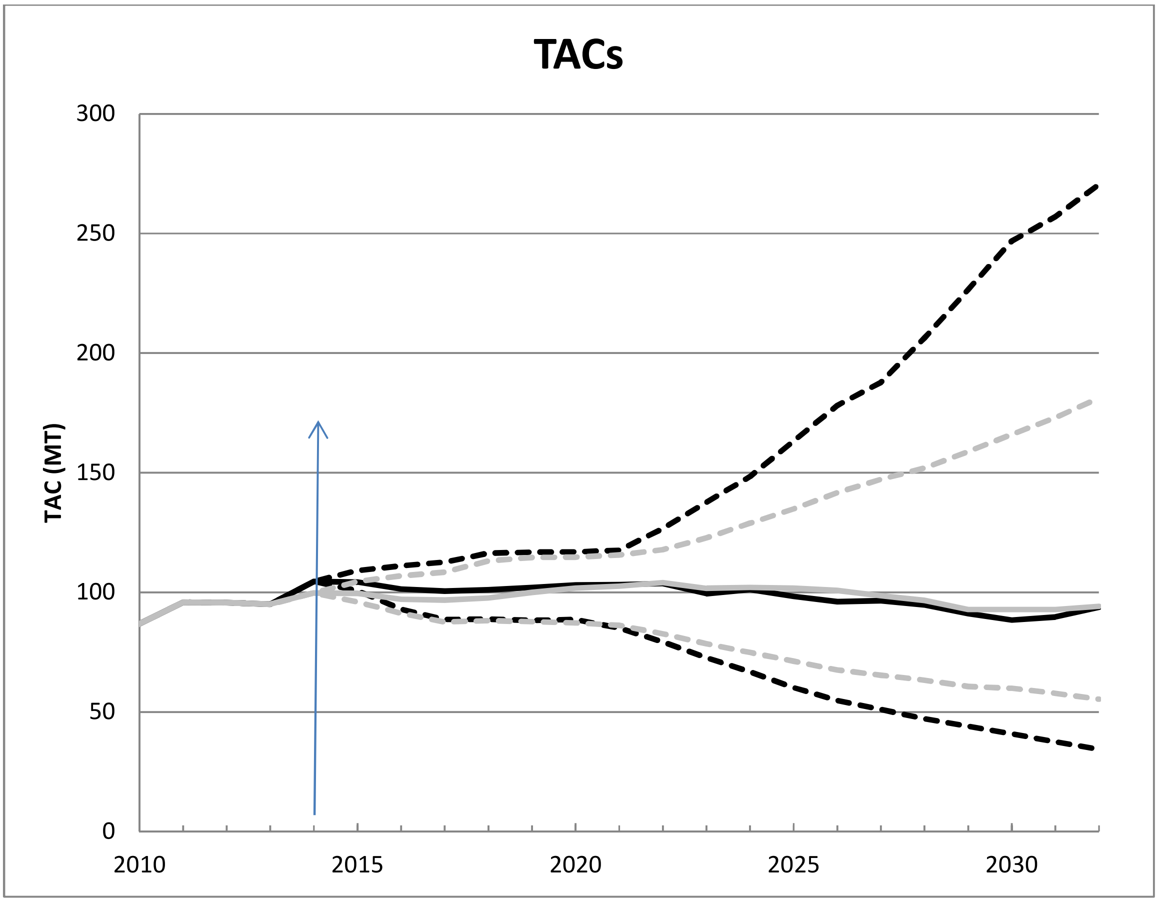


Figure 5: Preliminary **Gough** CMP median trajectories for **CMP20**, **CMP20 + metarule1 and CMP20 + metarule 2 for the robustness test R1 which assumes 75% of all lobsters are removed from the population in 2014**.

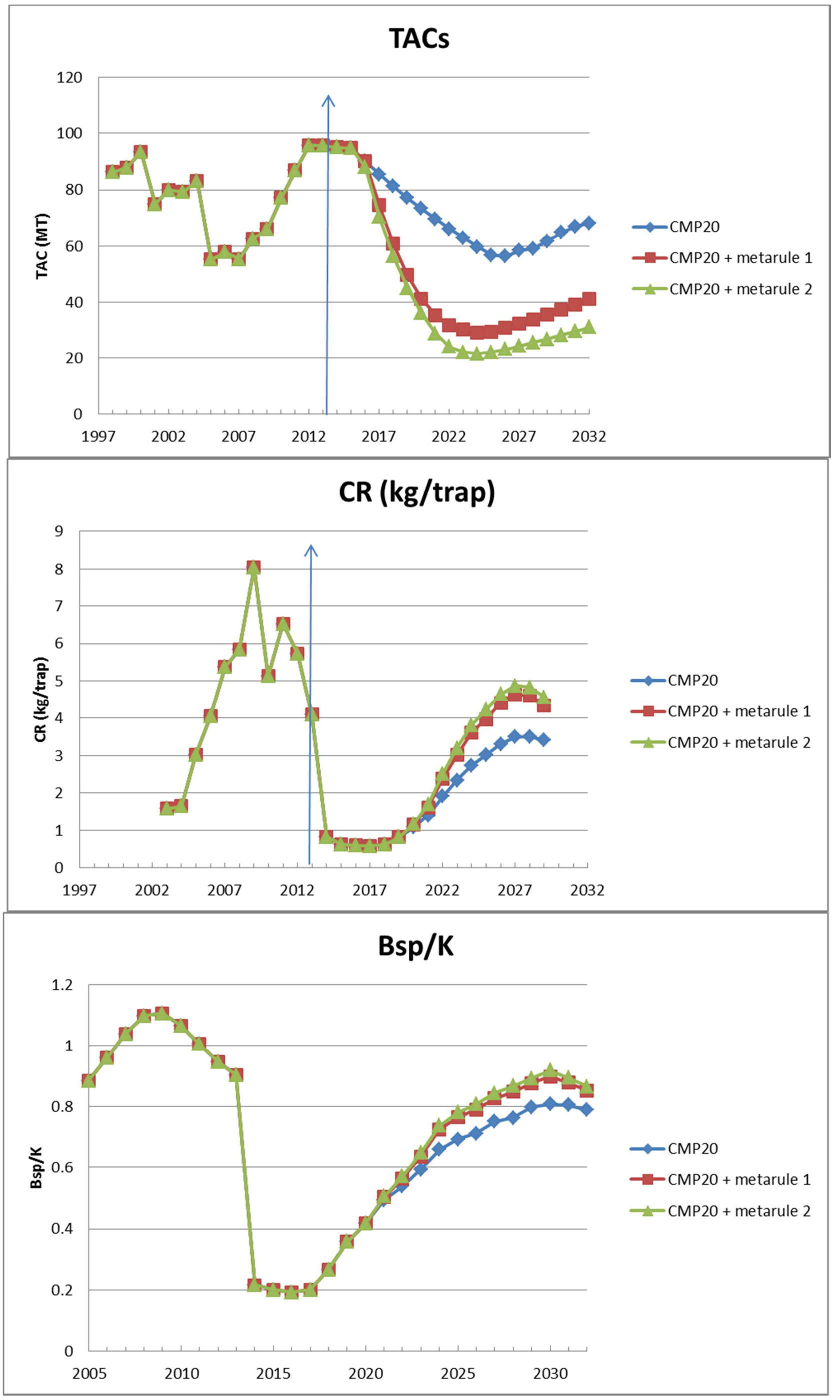


Figure 6: Preliminary **Gough** CMP simulation results for **CMP20** and **CMP20 + metarule1 for the robustness test R1 which assumes 75% of all lobsters are removed from the population in 2014**. Median, 5th and 95th percentile trajectories are shown. Vertical arrows show the start of the projection period.

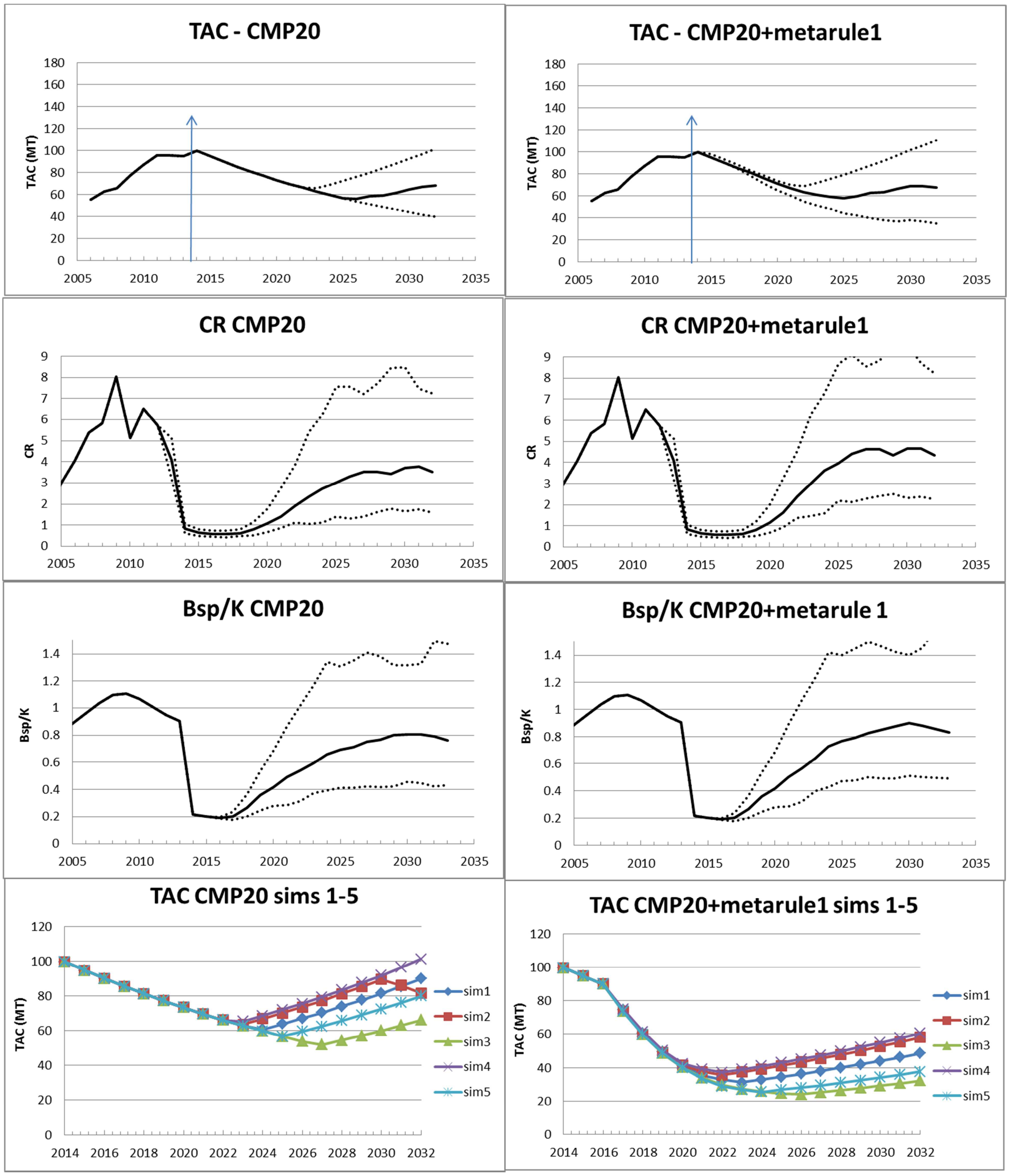
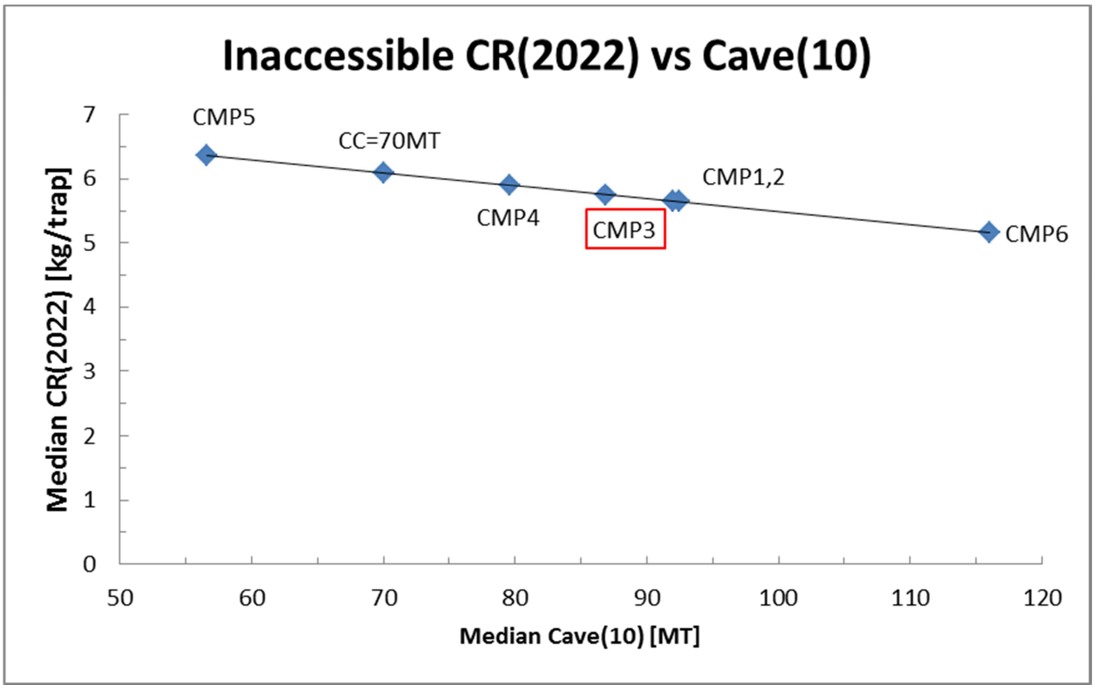
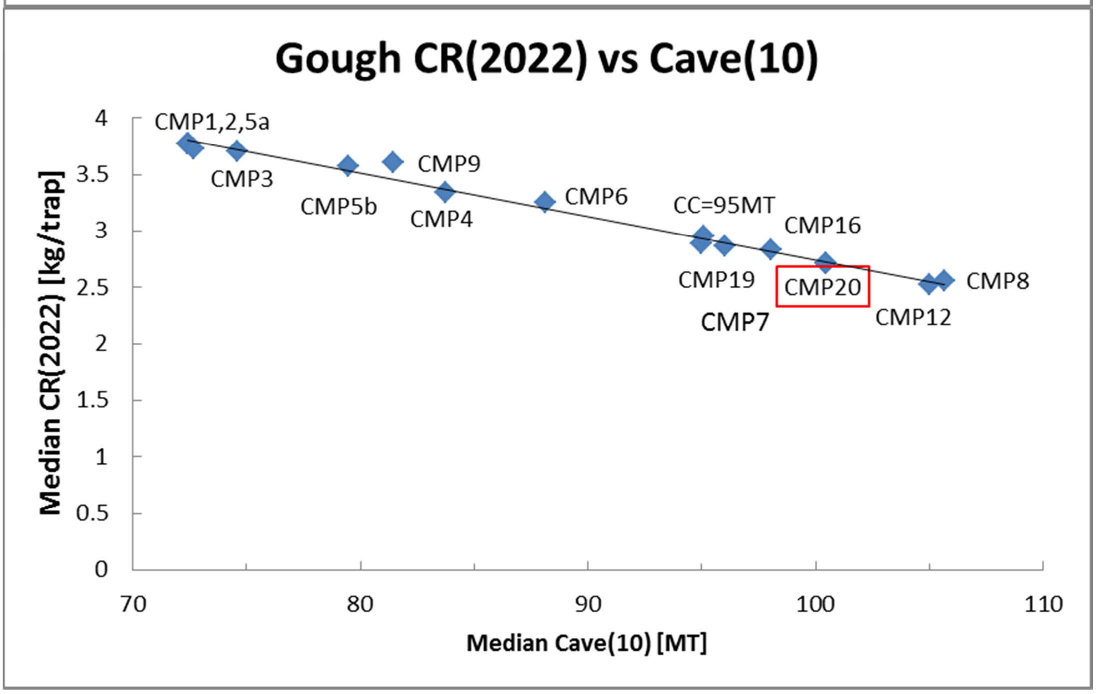


Figure 7: Plots of the median catch rate (CR) values expected in 2022 against the associated median Cave(10) values for Inaccessible and Gough. The straight line shows a linear regression line through the data points. The recommended CMPs are shown with a red rectangle.





Appendix 1: Updated Inaccessible assessment results

Johnston and Butterworth (2014) report updated assessment results for both Gough and Inaccessible island. The results for Inaccessible, whilst stated correspond to *M*=0.2, were actually for *M*=0.1. Here amended results are reported for the reference case inaccessible assessment using *M*=0.2, as well as results for Robustness test R1, which forces all selectivity functions to be flat at larger sizes (i.e. domed-selectivity is prevented), as well as estimating the female growth parameter t0 (which is fixed at -15.0 for the RC).

Table 1a reports model assessment results for both the RC *M*=0.1 and *M*=0.2,as well as for robustness test R1. Figure A1a-c reports the updated RC (M=0.2) model fits to data and estimated biomass trends and selectivity functions. Figures A2a-b are similar but for the robustness trial R1.

Table A1: Inaccessible 2014 assessment results. The 2013 assessment results are reported to allow comparison. The shaded values are fixed on input. Values in parentheses are estimated σ values.

	2013 assessment	**2014 assessment (male and female μ values all estimated) M=0.1**	**2014 RC assessment (male and female μ values all estimated) Corrected M=0.2**	**2014 assessment Robustness test R1 (male and female μ values all fixed=0 and female t0 estimated)**
# parameters	**42**	**69**	**69**	**34**
K	1284	1569	1468	351
h	0.91	0.91	0.94	0.98
M	0.2	**0.1**	**0.2**	**0.2**
d (discard mortality rate)	0.1	0.1	0.1	0.1
F_{2009} fixed at	0.3	0.3	0.3	0.3
Female t0	-15.0	-15.0	-15.0	-6.77
Male selectivity μ 90-00	0.023	All μ values estimated separately for male and females for years for which CAL data are available	All μ values estimated separately for male and females for years for which CAL data are available	All μ values fixed at 0 (i.e. selectivity flat at larger ages)
Male selectivity μ 01-03	0.013			
Male selectivity μ 04-05	0.001			
Male selectivity μ 06+	0.032			
Male selectivity μ 12+	-			
Female selectivity μ 90-00	0.149			
Female selectivity μ 01-03	0.179			
Female selectivity μ 04+	0.198			
Female selectivity μ 12+	-			
θ	0.522	0.291	0.321	0.366
-lnL total	-21.83	-6.95	-10.48	1.53
-lnL CPUE T	-28.83	-10.21	-11.46	-11.27
-lnL CPUE longline	-22.97	-4.94 (0.111)	-6.23 (0.181)	-5.97 (0.195)
-lnL CPUE Survey Leg1	-5.86	-5.27 (0.214)	-5.23 (0.218)	-5.30 (0.210)
-lnL CAL T	-10.97	-62.02	-78.12	57.33
-lnL CAL onboard observer	12.28	-30.45 (0.066)	-45.35 (0.064)	79.73 (0.090)
-lnL CAL Survey Leg 1	-23.15	-31.57 (0.078)	-32.77 (0.077)	-22.40 (0.085)
SR1 pen; μ pen	5.02; -	2.14; 4.38	1.95; 3.95	2.11; -
-lnL discard	3.75	3.60	3.58	5.62
Bsp(1990)/Ksp	0.49	0.27	0.30	0.34
Bsp(2012)/Ksp	0.82	0.83	0.83	0.81
Bsp(2013)/Ksp	0.81	0.85	0.84	0.80
Bsp(2014)/Ksp	-	0.87	0.84	0.81
Bsp(2013)	1041	1335	1228	282
Bsp(2011)/Bsp(1990)	1.70	3.00	2.76	2.38
Bsp(2012)/Bsp(1990)	1.68	3.08	2.79	2.38
Bsp(2013)/Bsp(1990)	1.69	3.16	2.81	2.36
Bsp(2014)/Bsp(1990)	-	3.23	3.23	2.38
Bexp(2012)/Bexp(1990)	1.52	3.47	3.08	2.52
Bexp(2013)/Bexp(1990)	-	3.88	3.44	2.75
Program	Test4.*	Inacran.tpl; iran6.rep	Inacran.tpl; iran8.rep	Zt.tpl, .rep

Figure A1a: Inaccessible RC assessment (allowing for time varying and domed shaped selectivity).

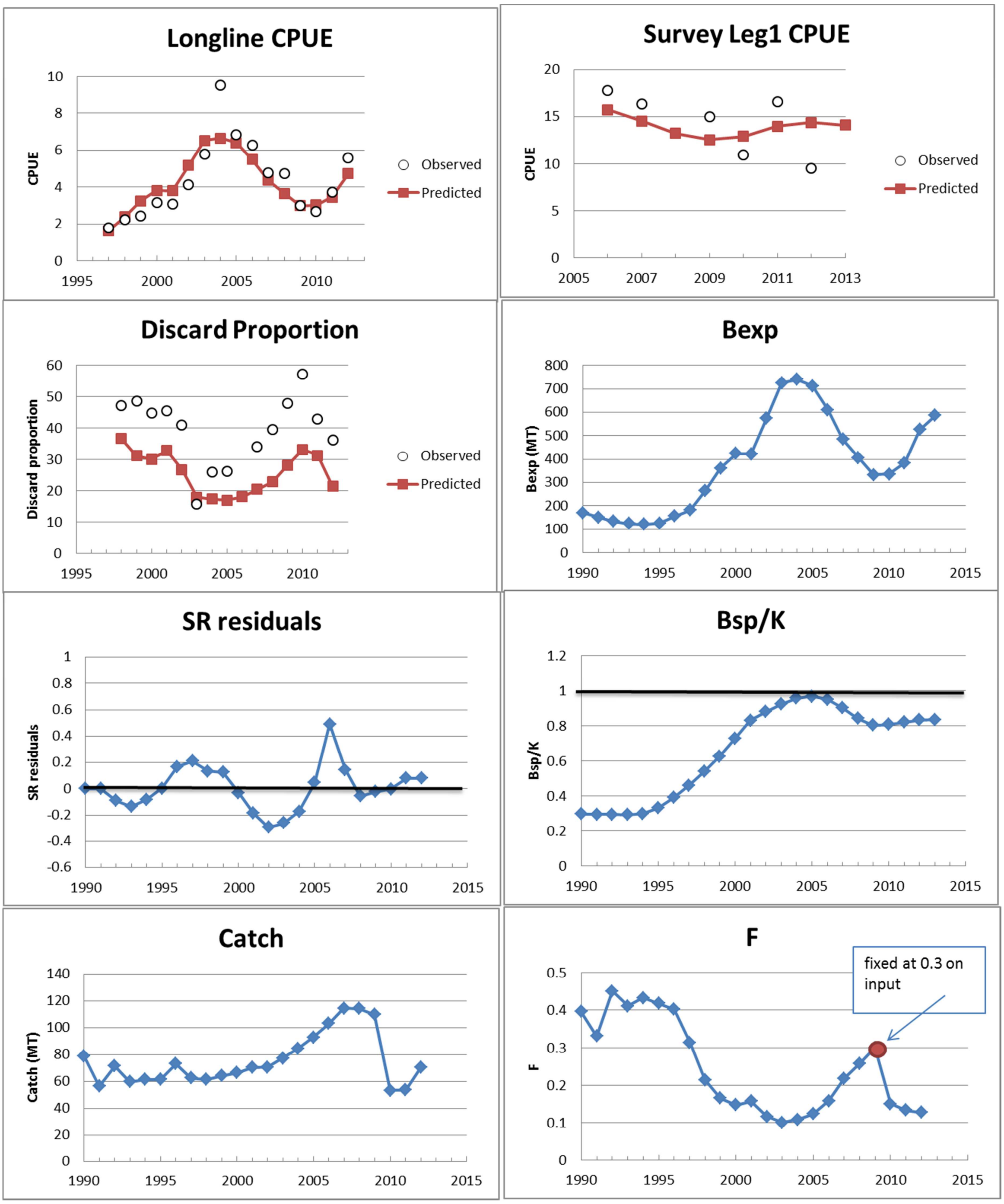


Figure A1b: Inaccessible RC assessment (allowing for time varying and domed shaped selectivity).

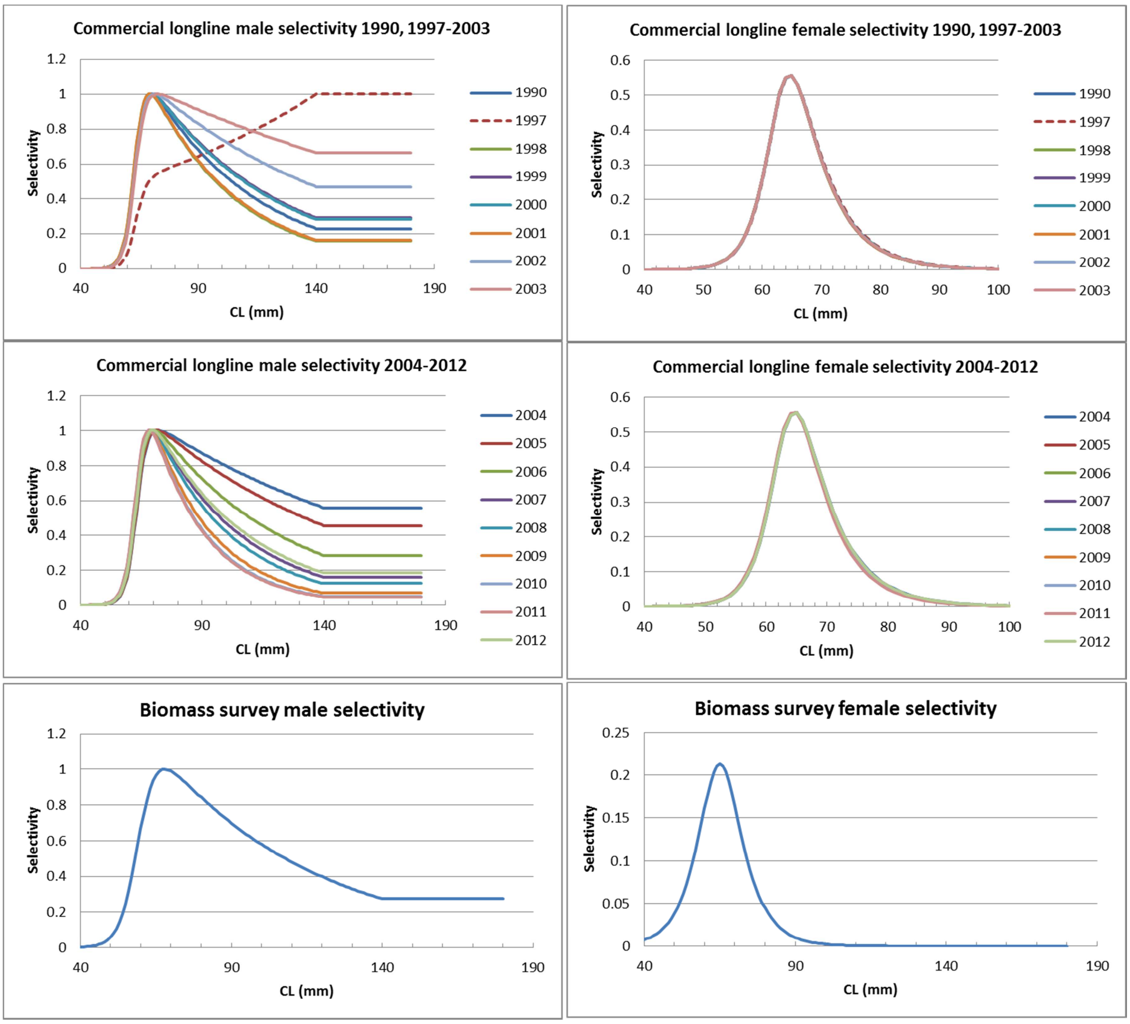


Figure A1c: Inaccessible RC assessment (allowing for time varying and domed shaped selectivity).

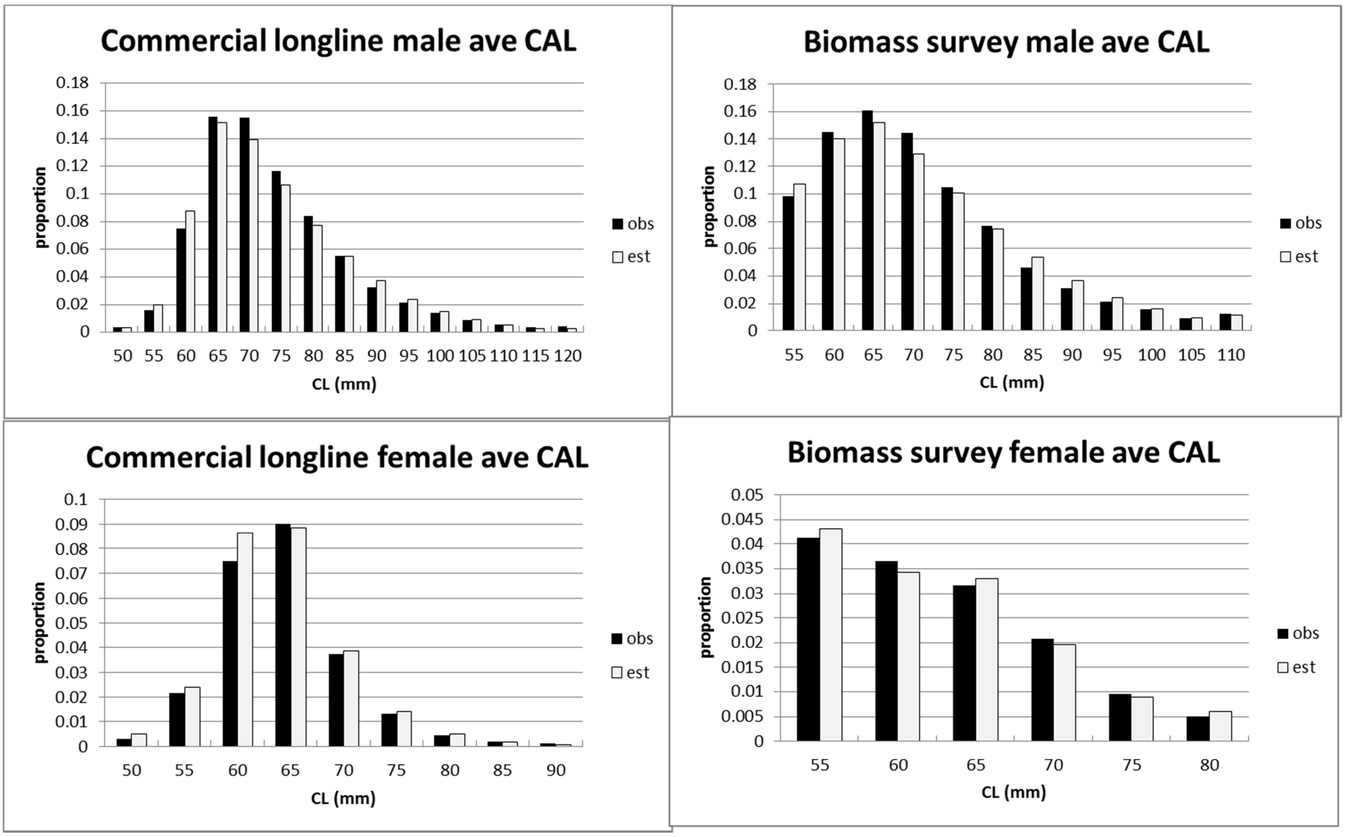


Figure A2a: Inaccessible Robustness R1 (fixes all selectivities to be flat).

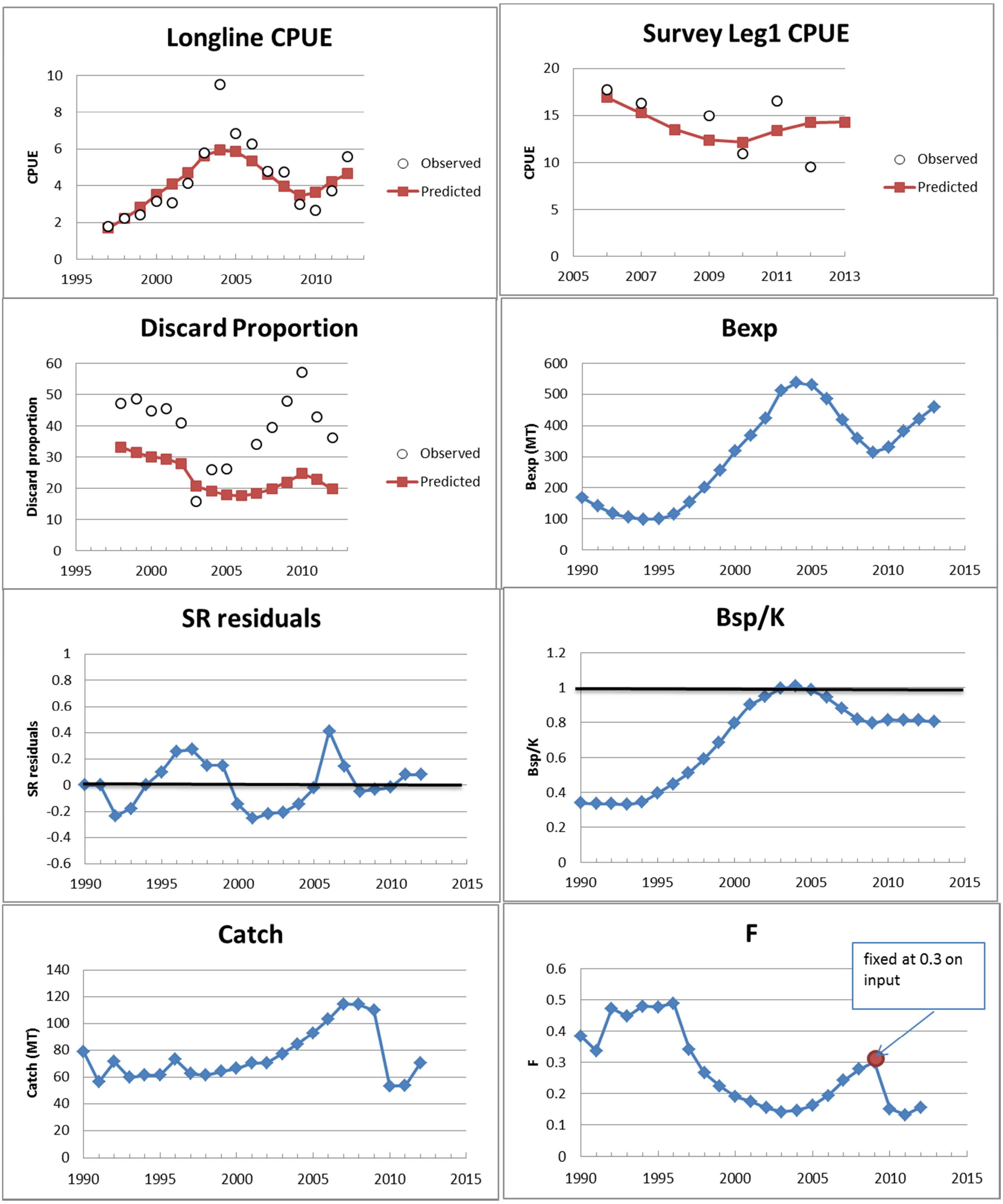


Figure A2a: Inaccessible Robustness R1 (fixes all selectivities to be flat).

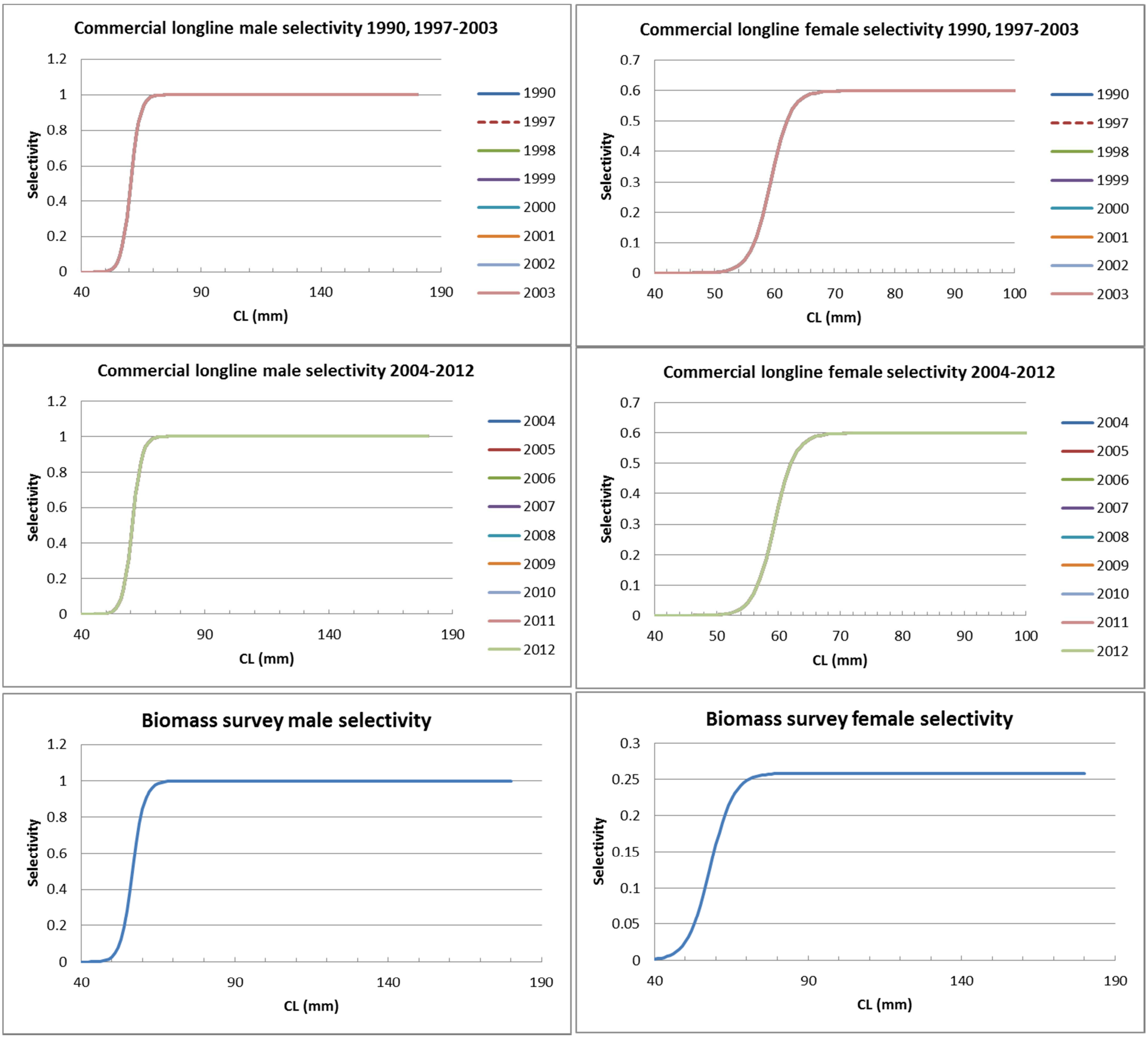


Figure A2a: Inaccessible Robustness R1 (fixes all selectivities to be flat).