Re-tuning of OMP-2008 using updated 2010 Operating Models for the South Coast Rock Lobster Resource to provide OMP-2010

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Summary

This document provides detailed specifications for population projections under future possible catch series, and details of the OMP. Based on updated operating models OMP-2008 is re-tuned to attain the same median recovery target of a 20% increase in spawning biomass from 2006 to 2025 as agreed two years previously. Results are not greatly changed, with new projections of spawning biomass showing a little greater uncertainty under the resultant OMP-2010 than was the case previously.

Introduction

An OMP for setting the TAC for South Coast rock lobster was developed and first implemented in 2008[1] (Johnston and Butterworth 2008a). This OMP was intended to be implemented for two years and then a review of the underlying operating models would decide whether this OMP could be implemented "as is" for a further two years (2010 and 2011) or if updates/retuning of this OMP would be required. Recently the Rock Lobster Scientific Working Group (SWG) has reviewed the 2010 updated assessment models of the resource (Johnston and Butterworth 2010a). The decision was made by the SWG that these assessments showed some important changes with respect to the possible productivity of the resource compared to the 2008 operating models upon which the current OMP-2008 has been simulation tested. A set of five updated operating models (OMs) were selected against which to re-test a revised OMP. These OMs are reported in Johnston and Butterworth (2010b), and are:

- Model 3 (MARAM time varying selectivity)
- Model 4 (OLRAC time varying selectivity)
- Model 3ES (effort saturation)
- Model 3 CDW(down-weight of catch-at-length data by a factor of 0.1)
- Model 3 *h*=0.8 (*h* fixed at value of 0.8)

The revised OMP, OMP-2010, was to have the same structural form as OMP-2008, except that it was to be re-tuned so that median $B^{sp}_{2025}/B^{sp}_{2006}$ remains 1.20 when simulation tested with Model 3, i.e. a spawning biomass increase of 20% over the 2006-2025 period, as had been the objective when OMP-2008 was chosen.

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[1] 2008 refers to the 2008/2009 season

Simulation Testing of OMP-2010

As in 2008, 100 simulations of each operating model projected ahead under TACs calculated using the retuned OMP are calculated. Each simulation has random noise added to various components of the model (the selectivity and the recruitment) and input data (CPUE), as described below. The simulation method is identical to that used in 2008, except that in the forward projections of the simulations the split of the global TAC between the three fishing areas is now assumed to be proportional to the recent (2004-2008) average fishing mortalities in each area, in contrast to the fixed proportions that were assumed in 2008.

Assumptions required for future projections for OMP testing

Summary of current 2010 assessments (OMs):

- Fit to CPUE and CAL data up to and including 2008
- The assessments include the observed catch for 2009; thus the assessment ends at the start of 2010, i.e. projections start at beginning of 2010.

Thus:

- The OMP thus needs to sets its first OMP TAC for 2010
- The OMP uses the observed CPUE for 2004-2008, and then model-generated CPUE (with noise) for 2009+
- The OMP TAC for year *y* uses CPUE information from 2003 to year (*y*-2), and catches from 1973 to year (*y*-1).

When projecting the population forwards for the simulation testing of various OMP candidates, a number of assumptions need to be made for the operating models to be used. The framework adopted for these is as follows.

1. Stock-Recruit residuals

For 2001+ $$R_y = \frac{\alpha B_y^{sp}}{\beta + (B_y^{sp})} e^{\varepsilon_y} \qquad \varepsilon_y \sim N(0, \sigma_R^2) \tag{1}$$

where σ_R =0.4

The assessment provides values for $\hat{N}_{2010,a}$ for $a \geq 1$, under the assumption that ε_y are estimated for 1974-2000 (but constrained to average zero) and fixed at 0.08 ($\sigma_R^2/2$) for 2001+ so that recruitment (relative to the deterministic prediction of the stock-recruit relationship) remains at its average value for 1974-2000. To allow for random variation in recruitment from 2001 to 2009 when projecting, the following adjustments are made to the numbers at age to start the projections:

$$\hat{N}_{2010,a} \rightarrow \hat{N}_{2010,a} e^{\varepsilon_{2010-a}} \qquad \text{for } a = 1,2...7 \tag{2}$$

where the ϵ_{2010-a} are generated from $N(0, \sigma_R^2)$

This does not introduce any substantial bias into computations, as any catch prior to 2010 from the cohorts concerned is minimal.

However, given indications of some temporal auto-correlation in the stock recruit residuals an AR(1) process is assumed. The associated auto-correlation s_R is estimated by:

$$s_R = \sum_{y=1974}^{1999} \hat{\varepsilon}_{y+1}\hat{\varepsilon}_y \Big/ \sum_{y=1974}^{1999} \hat{\varepsilon}_y^2 \qquad (3)$$

Then instead of generating the ε_y from $N(0,\sigma_R^2)$, we use

$$\varepsilon_{y+1}^s = s_R \varepsilon_y^s + \sqrt{1-s_R^2}\,\eta_y^s \qquad \eta_y^s \sim N(0,\sigma_R^2). \qquad (4)$$

This equation is first applied for y=2001 to provide ε_{2001}^y with an input of $\varepsilon_{2000}^s = \hat{\varepsilon}_{2000}$, i.e. the value estimated in the assessment.

2. Proportional split of recruitment R_y by Area

For each Area A, the proportional split of recruitment, $\lambda_y^{*,A}$:

$$R_y^A = \lambda_y^{*,A} R_y \qquad (5)$$

where

$$\lambda_y^{*,A} = \frac{\lambda^A e^{\varepsilon_{A,y}}}{\sum_A \lambda^A e^{\varepsilon_{A,y}}} \qquad (6)$$

and

$$\varepsilon_{A,y} \sim N(0,\sigma_\lambda^2); \qquad \sigma_\lambda = 1.0$$

has been estimated from **1973** to **2001**

The random effects $\varepsilon_{A,y}$ are treated as estimable parameters (in addition to the three λ^A parameters), but are constrained through the addition of a penalty function in the likelihood related to the assumption that they are normally distributed.

From these $\varepsilon_{A,y}$, the σ_ε^A for the standard deviation and s_λ^A the auto-correlation can be calculated:

$$s_\lambda^A = [\sum_{y=1973}^{2000} \hat{\varepsilon}_{A,y+1}\hat{\varepsilon}_{A,y}] / \sum_{y=1973}^{2000} \hat{\varepsilon}_{A,y}^2\,, \qquad (7)$$

$$\sigma_\lambda^A = \sqrt{[\sum_{y=1973}^{2001} \hat{\varepsilon}_{A,y}^2]/(2001-1974+1)} \qquad (8)$$

For 2002+, $\lambda_y^{*,A,s}$ need to be generated where for each year:

$$\lambda_y^{*,A,s} \rightarrow \frac{\lambda_y^{*,A,s}}{\sum_{A=1}^{3} \lambda_y^{*,A,s}} \qquad \text{so that proportions sum to 1} \qquad (9)$$

where s is the simulation index.

The $\lambda_y^{*,A,s}$ are generated from $\hat{\lambda}^A e^{\varepsilon_y^{A,s}}$, where:

$$\varepsilon_{y+1}^{A,s} = s_\lambda^A \varepsilon_y^{A,s} + \sqrt{1-{s_\lambda^A}^2}\,\eta_y^{A,s} \qquad \text{with } \eta_y^{A,s} \text{ from } N(0,(\sigma_\varepsilon^A)^2).$$

The values required to initiate the projections are obtained by updating equation (2) as follows:

$$N_{2010,a}^{A} \rightarrow \hat{N}_{2010,a} e^{\varepsilon_{2010-a}} \lambda_{2010-a}^{*A,s} \qquad \text{for } a=1,2,3,4 \text{ (i.e. } \lambda \text{ generated)} \qquad (10)$$

$$\rightarrow \hat{N}_{2010,a} e^{\varepsilon_{2010-a}} \hat{\lambda}_{2010-a}^{A} \qquad \text{for } a = 5,6,7 \text{ (i.e. } \lambda \text{ as estimated in assessment)}$$

3 Selectivity

MARAM selectivity model (Model 3)

Model 3 estimates $\delta_y^{m/f,A}$ for **1995** to **2008** (see Johnston and Butterworth (2008b) Equation 1, reproduced below as Equation 11):

$$S_{y,l}^{m/f,A} = \frac{1}{1+e^{-\ln 19(l-(l_{50}^{m/f,A}+\delta_y^{m/f,A})/\Delta^{m/f,A}}} \qquad (11)$$

The δ values are assumed to change from year to year as an AR1 process.

Thus for 2009+: $$\delta_y^{m/f,A,s} = \bar{\delta}^{m/f,A} + \eta_y^{m/f,A,s} \qquad (12)$$

where $$\eta_{y+1}^{m/f,A,s} = s_\delta^{m/f,A} \eta_y^{m/f,A,s} + \sqrt{1-{s_\delta^{m/f,A}}^2}\,\chi_y^s \qquad (13)$$

with χ_y^s from $N(0,(\sigma_\delta^{m/f,A})^2)$

where the auto-correlation $$s_\delta^{m/f,A} = \left[\sum_{y=1995}^{2007} \hat{\eta}_{y+1}\hat{\eta}_y\right] / \sum_{y=1995}^{2007} \hat{\eta}_y^2 \qquad (14)$$

and where $\bar{\delta}^{m/f,A}$ and $\sigma_\delta^{m/f,A}$ are calculated as the mean and standard deviation of the 1995 to 2008 estimates.

Note that for Area 3 where there are two selectivity functions (see Johnston and Butterworth, 2008b):

$$S_{y,l}^{m/f,3} = (1-\mu) S1_{y,l}^{m/f,3} + \lambda\mu S2_l^{m/f,3} \qquad (15)$$

where

$S1_{y,l}^{m/f,3}$ is the original selectivity function (as used for other Areas) and simulated for the future by Equation 12,

$S2_l^{m/f,3} = e^{-(l-l^*_{m/f})^2/\omega^2}$ is a normal-shaped selectivity function which remains fixed over time, and

μ remains constant in the future at the value estimated in the assessment.

OLRAC selectivity model (Model 4)
See Johnston and Butterworth (2008b) Equations 8-13 reproduced below as Equations 16-21:

$$\bar{S}_l^{m/f,A} = \frac{1}{1+e^{-\ln 19(l-l_{50}^{m/f,A})/\Delta^{m/f,A}}} \tag{16}$$

$$S_{y,l}^{m/f,A} = \bar{S}_l^{m/f,A}\alpha_{y,l}^{m/f,A} \tag{17}$$

where

$$\alpha_{y,l}^{m/f,A} = \frac{x_y^{m/f,A}}{X_y^{m/f,A}} \qquad l \le 50 \tag{18}$$

$$\alpha_{y,l}^{m/f,A} = \frac{x_y^{m/f,A} + (l-50)(1-x_y^{m/f,A})(l_{kink}-50)}{X_y^{m/f,A}} \qquad 50 \le l \le l_{kink} \tag{19}$$

$$\alpha_{y,l}^{m/f,A} = \frac{1}{X_y^{m/f,A}} \qquad l > l_{kink} \tag{20}$$

and where:

$$X_y^{m/f,A} = \left\{\sum_{l=l1}^{50} x_y^{m/f,A} + \sum_{l=51}^{l_{kink}}\left[x_y^{m/f,A} + \frac{(l-50)(1-x_y^{m/f,A})}{l_{kink}-51}\right] + \sum_{l=l_{kink}}^{l2} l\right\}/(l2-l1+1) \tag{21}$$

The $x_y^{m/f,A}$ are the key time dependent parameters – these are estimated in the assessment for **1973-2008**.

The estimates of past values show strong auto-correlation, though that in part arises from the penalty on changes between years in the estimation procedure (Johnston and Butterworth, 2008b). Future values are generated by a process similar to the AR1 process for the MARAM model in the previous section.

Thus for 2009+: $$x_y^{m/f,A,s} = \bar{x}^{m/f,A} + \eta_y^{m/f,A,s} \tag{22}$$

where $$\eta_{y+1}^{m/f,A,s} = s_x^{m/f,A}\eta_y^{m/f,A,s} + \sqrt{1-s_x^{m/f,A^2}}\chi_y^s \tag{23}$$

with χ_y^s from $N(0,(\sigma_x^{m/f,A})^2)$

where the auto-correlation $$s_x^{m/f,A} = \left[\sum_{y=1973}^{2007}\hat{\eta}_{y+1}\hat{\eta}_y\right] / \sum_{y=1973}^{2007}\hat{\eta}_y^2 \tag{24}$$

and where $\bar{x}^{m/f,A}$ and $\sigma_x^{m/f,A}$ are calculated as the mean and standard deviation of the 1973 to 2008 estimates of $\hat{x}_y^{m/f,A}$.

4. Future data generation

Future CPUE values need to be generated. Whichever model is fit, there is a model estimate for $CPUE_y^A$ for past years. Projected into the future, the model provides expected $CP\hat{U}E_y^A$ values for each year and Area. Future (2009+) CPUE values for simulation *s* are generated for each area A from:

$$CPUE_y^{A,s} = C\hat{PUE}_y^{A,s} \exp(\varepsilon_y^{A,s}) \qquad \varepsilon_y^{A,s} \sim N(0,(\sigma_{CPUE}^A)^2)) \tag{25}$$

where the σ_{cpue}^A values are as estimated in the corresponding assessment.

Note: the effort saturation operating model assumes that the effort saturation effect does not occur in the future. Figure A1 in the Appendix shows the effort saturation estimates of $\bar{E}$ (the level above which effort saturation takes place), along with the values of effort for each area for the 1976-2008 period, and indicates that this level was exceeded only very seldom in the past.

TAC rule for OMP testing

OMP 2008 consists of an algorithm that calculates the TAC for the resource using CPUE data collected from each of three areas (New Areas 1, 2 and 3).

Note that the TAC for season y+1 is based upon the CPUE series that ends in season *y*-1, i.e. the TAC recommendation for 2010 would be based on a CPUE series that ended with the most recent CPUE value available at the time a recommendation was requested which would be for 2008.

1. TAC setting algorithm

The algorithm used to recommend the TAC for the South Coast Rock Lobster fishery for season *y*+1 is:

$$TAC_{y+1} = TAC_y [1 + \alpha(s_y - \delta)] h(r_y) \tag{26}$$

Where:

TAC_y is the TAC set (note NOT the catch taken) in season y ;

the value of α is set at 3.0;

s_y^A is the slope parameter from a regression of $\ln CPUE_y^A$ against y over the last five seasons' data (these will be for seasons *y*-5 to *y*-1 as data for season *y* will not be available at the time the recommendation is required) for each area *A*, and

$$s_y = \sum_{A=1}^{3} w^A s_y^A \tag{27}$$

where $w^A = \dfrac{\dfrac{1}{\sigma_S^{A^2}}}{\sum_{A'=1}^{3} (\dfrac{1}{\sigma_S^{A'^2}})}$ (28)

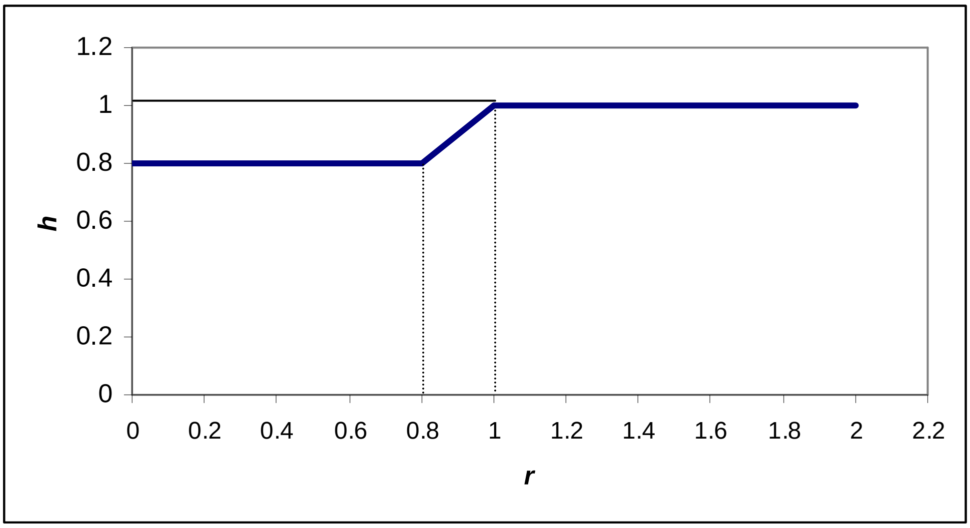
and σ_S^A is the standard error of the regression estimate of s_y^A subject to a lower bound of 0.15; and

δ is a control parameter value which has now been re-tuned to achieve the median recovery target of $B^{sp}_{2025}/B^{sp}_{2006}$ of 0.20 specified, for Model 3.

Further:

$$\begin{aligned} h(r) &= 0.8 \quad \text{for} \quad r \le 0.8 \\ &= r \quad \text{for} \quad 0.8 \le r \le 1.0 \\ &= 1.0 \quad \text{for} \quad r \ge 1.0 \end{aligned} \qquad (29)$$

i.e.:



where r is the ratio of recent area-averaged CPUE to that at the time the OMP commenced:

$$\overline{CPUE}_{init} = \frac{1}{3}\sum_{y'=2003}^{2005}\sum_{A=1}^{3}\lambda_A CPUE^A_{y'} \qquad (30)$$

$$\overline{CPUE}_{y} = \frac{1}{3}\sum_{y'=y-3}^{y-1}\sum_{A=1}^{3}\lambda_A CPUE^A_{y'} \qquad (31)$$

$$r_y = \frac{\overline{CPUE}_y}{\overline{CPUE}_{init}} \qquad (32)$$

and

$$\lambda_1 = 0.08$$
$$\lambda_2 = 0.87$$
$$\lambda_3 = 0.05 \, .$$

The CPUE weighting factors, λ_1, λ_2 and λ_3 relate to relative biomass in each area, and were calculated as follows. Using the estimated values of q and B^{exp} for 2010 from operating Model 3 (Johnston and Butterworth 2010b):

	q	B^{exp} (MT)
Area 1	0.00218412	565
Area 2	0.000571185	1598
Area 3	0.0023918	375

The relative biomass weights are thus: Area 1 = 565/2537 = 0.22
Area 2 = 1598/2537 = 0.63
Area 3 = 375/2537 = 0.15

In terms of CPUE what is therefore required is:

$$\begin{aligned}&0.22\,B^1 + 0.63B^2 + 0.15\,B^3\\ &= 0.22\frac{CPUE^1}{q_1} + 0.63\frac{CPUE^2}{q_2} + 0.15\frac{CPUE^3}{q_3}\\ &= 100.7\,CPUE^1 + 1103\,CPUE^2 + 63\,CPUE^3\end{aligned}$$

As the CPUE weights must sum to 1, it follows that the appropriate weighted average for CPUE is given by:

$$0.08\,CPUE^1 + 0.87\,CPUE^2 + 0.05\,CPUE^3$$

Inter-annual TAC constraint
A rule to restrict the inter-annual TAC variation to no more than 5% up or down from season to season is applied, i.e.:

$$\begin{aligned}&\text{if } TAC_{y+1} > 1.05TAC_y \qquad TAC_{y+1} = 1.05TAC_y\\ &\text{if } TAC_{y+1} < 0.95TAC_y \qquad TAC_{y+1} = 0.95TAC_y\end{aligned} \tag{33}$$

Summary statistics

Results reported are the median and 5th and 95th percentiles of 100 simulations for the following statistics. [Note that in order to produce statistics that can be directly comparable to those produced in 2008, some statistics involve past TAC values already set.]

<u>Average Annual Catch</u>
C_{ave}^{7}= average annual catch (all areas combined) over the 2006-2012 period
C_{ave}^{10} = average annual catch (all areas combined) over the 2006-2015 period
C_{ave}^{20}= average annual catch (all areas combined) over the 2006-2025 period

<u>Average annual catch variation</u>
V^7= average inter-annual catch variation (expressed as a percentage) over the 2006-2012 period
V^{10}= average inter-annual catch variation (expressed as a percentage) over the 2006-2015 period

V^{20}= average inter-annual catch variation (expressed as a percentage) over the 2006-2025 period

Spawning biomass trend values

B^{sp} (15/06) = spawning biomass at the start of 2015 compared to that at the start of 2006

B^{sp} (25/06) = spawning biomass at the start of 2025 compared to that at the start of 2006

Results

Model 3 has been used to re-tune OMP-2008 (to form the re-tuned OMP-2010) so that the median B^{sp} (25/06) over 100 simulations is 1.20 (the current management target). The control parameter δ required to achieve this target is equal to -0.029.

Simulation results under the new re-tuned OMP 2010 for all five operating models are presented in table 1. Medians and 5th and 95th percentiles are presented.

Figure 1 shows the median expected TAC and B_{sp} trajectories for all five operating models. Figure 2 plots the medians shown in Figure 1 on a single plot.

Figure 3 compares the median expected TAC trajectories for Model 3 between the previous OMP 2008 and the re-tuned OMP 2010.

Discussion

Table 1 shows that the TAC prognosis for the next few years under Model 3 is more optimistic than projected two years previously, with a turn-around in median terms next year.

The probability interval for B^{sp} (2025/2006) under Model 3 is slightly wider than two years ago. The extent of recovery is reasonably robust across the OMs considered, though it is on the low side for Model 4.

A concern arising from the plots in Figure 1 is that median catch and spawning biomass trajectories start to decline in about 2018 for most cases. Furthermore the lower PIs for the biomass projections all show downward trends. Future work towards the 2012 OMP revision should seek to better avoid such possibilities.

Reference List

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Table 1: Summary performance statistics for OMP-2010 for the five different operating models. Medians with 5th and 95th percentiles are reported. The final column reports results for OMP-2008 as evaluated using Model 3 in 2008.

	Model 3	Model 4	Model 3 CDW	Model 3 ES	Model 3 h=0.8	2008 Model 3 and OMP-2008
C^{7}_{ave} (2006-2012) t	359 [350; 359]	359 [359; 359]	359 [355; 359]	359 [352; 363]	358 [347; 358]	346 [343; 363]
C^{10}_{ave} (2006-2015) t	365 [342; 370]	371 [355; 371]	369 [351; 371]	368 [350; 377]	356 [333; 371]	340 [323; 369]
C^{20}_{ave} (2006-2025) t	394 [322; 344]	407 [353; 450]	406 [326; 462]	393 [349; 446]	373 [297; 433]	350 [296; 408]
V^{7} (2006-2012) %	4 [3; 4]	4 [4; 4]	4 [3; 4]	4 [3; 4]	4 [3; 4]	4 [3; 4]
V^{10} (2006-2015) %	4 [3; 4]	4 [4; 4]	4 [4; 4]	4 [3; 4]	4 [3; 4]	4 [3; 4]
V^{20} (2006-2025) %	4 [4; 5]	4 [4; 5]	4 [4; 4]	4 [4; 4]	4 [4; 5]	4 [4; 5]
TAC(2008) t	365	365	365	365	365	363 [363; 363]
TAC(2009) t	345	345	345	345	345	345 [345; 357]
TAC(2010) t	328	328	328	328	328	328 [328; 356]
TAC(2011) t	344 [318; 344]	344 [344; 344]	344 [334; 344]	341 [322; 355]	343 [311; 344]	311 [311; 337]
TAC(2012) t	361 [328; 361]	361 [361; 361]	361 [344; 361]	357 [323; 372]	357 [314; 361]	296 [296; 330]
B^{sp} (2015/2006)	1.25 [1.06; 1.62]	1.21 [0.96; 1.64]	1.16 [0.96; 1.49]	1.20 [1.01; 1.53]	1.16 [0.99; 1.48]	1.24 [0.96; 1.68]
B^{sp} (2025/2006)	**1.20 [0.81; 1.77]**	**0.96 [0.58; 1.64]**	**1.06 [0.62; 1.84]**	**1.18 [0.85; 1.70]**	**1.16 [0.78; 1.65]**	**1.20 [0.87; 1.70]**
B^{sp} (2006/K)	0.28	0.23	0.35	0.30	0.29	0.34
B^{sp} (2010/K)	0.35 [0.29; 0.45]	0.28 [0.22; 0.38]	0.41 [0.34; 0.52]	0.36 [0.30; 0.46]	0.34 [0.29; 0.43]	0.42 [0.33; 0.57]
B^{sp} (2025/K)	0.33 [0.22; 0.49]	0.22 [0.14; 0.38]	0.37 [0.22; 0.64]	0.35 [0.26; 0.51]	0.34 [0.23; 0.48]	0.41 [0.29; 0.58]

Figure 1: Median annual TAC and B_{sp} trajectories with the 5[th] and 95[th] percentiles for the retuned OMP-2010 for all five operating models.

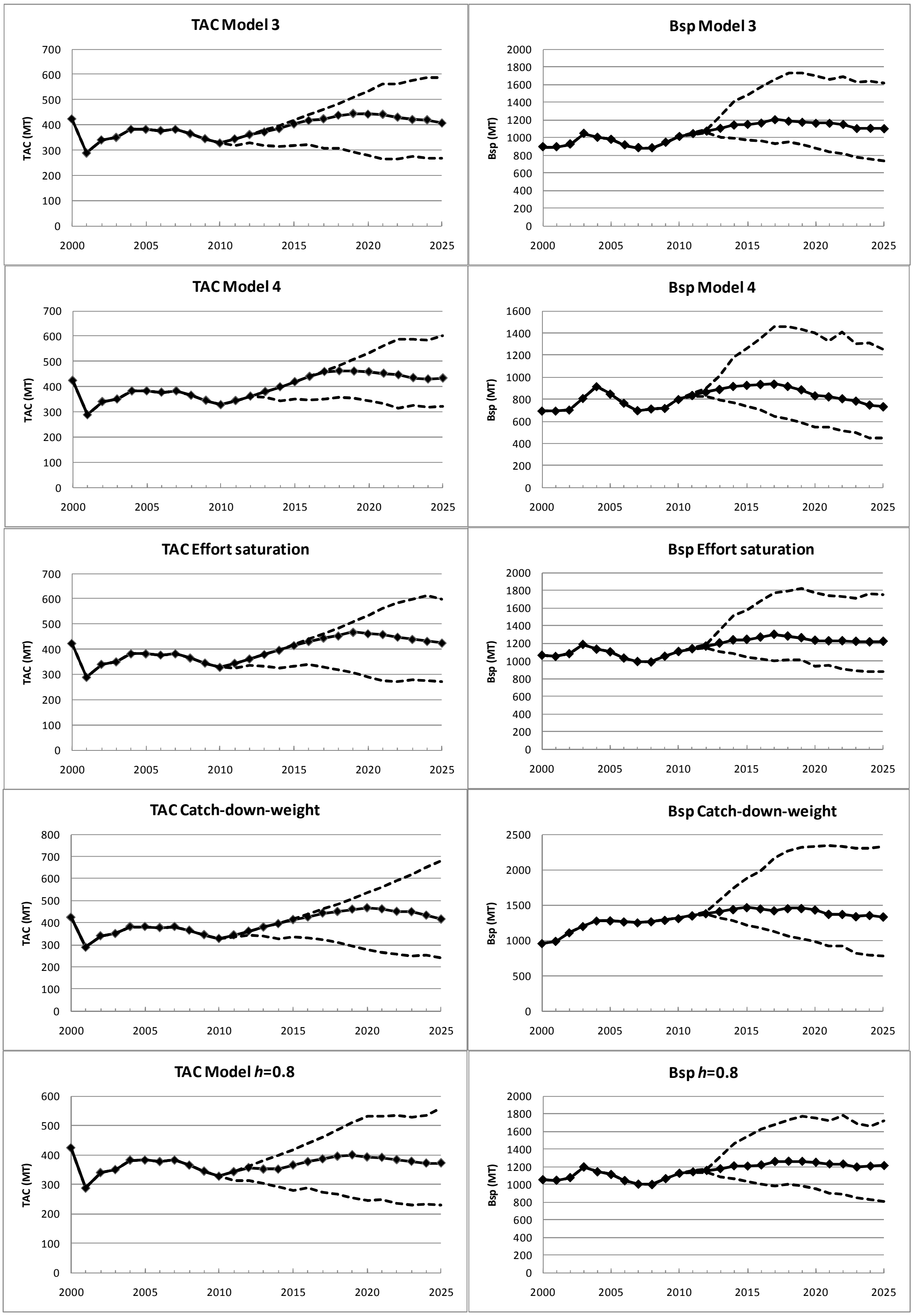


Figure 2: Comparison of median TAC, B_{sp}/K and $B_{sp}(y)/B_{sp}(2006)$ trajectories between the five operating models for the retuned OMP-2010

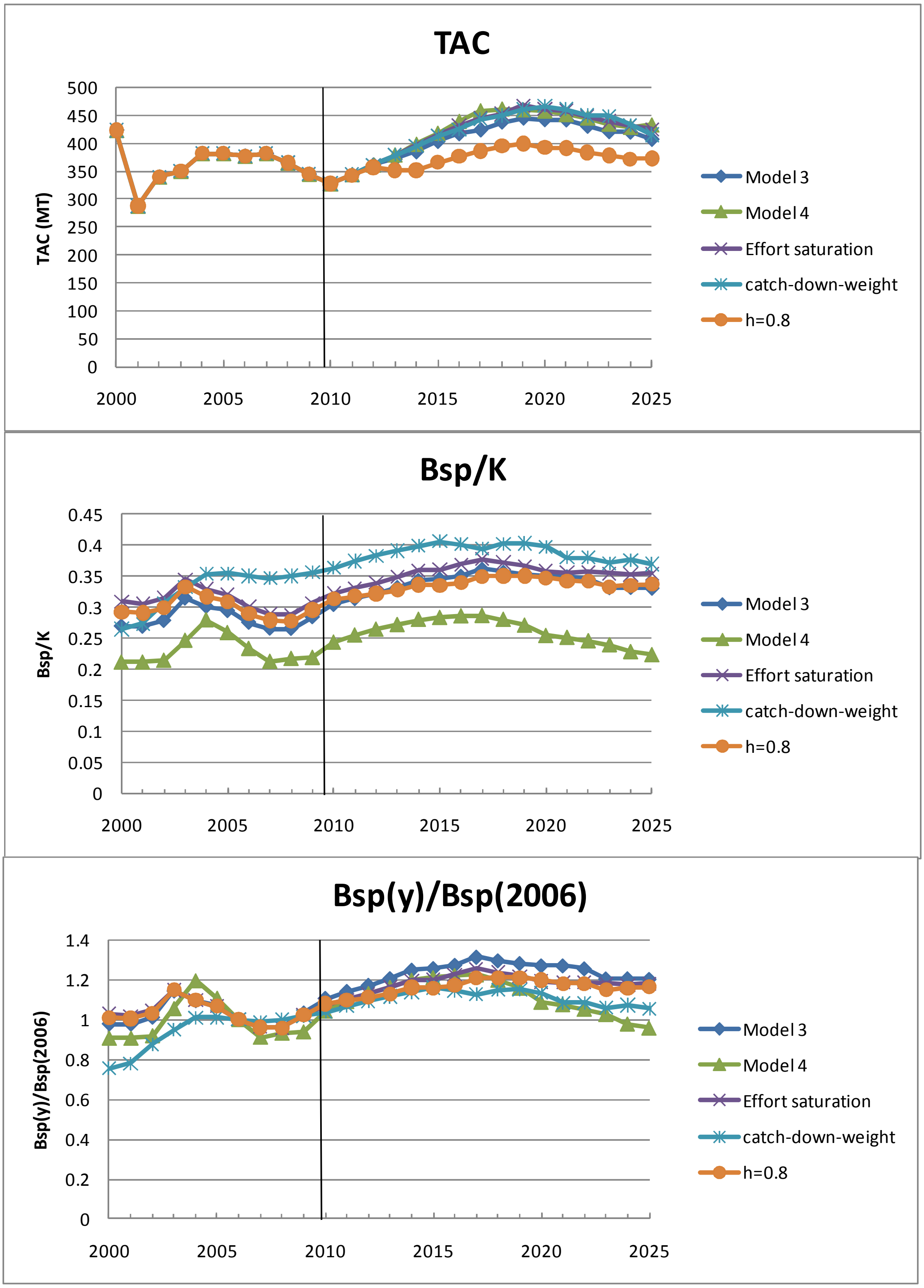


Figure 3a: Comparison of the Model 3 TAC median trajectory with 5th and 95th percentiles predicted under OMP-2008 (grey dashed lines) and the re-tuned OMP-2010 (black solid lines).

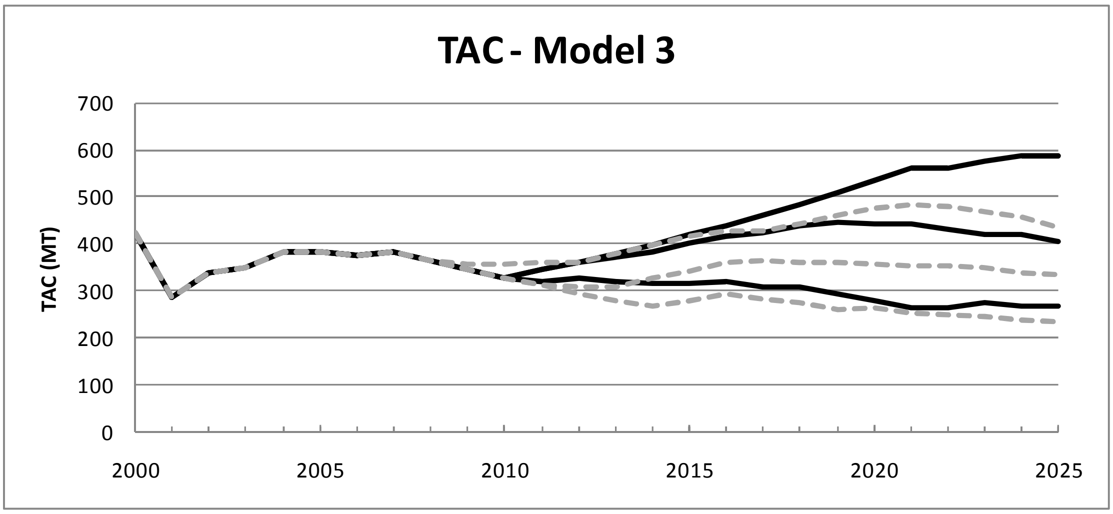
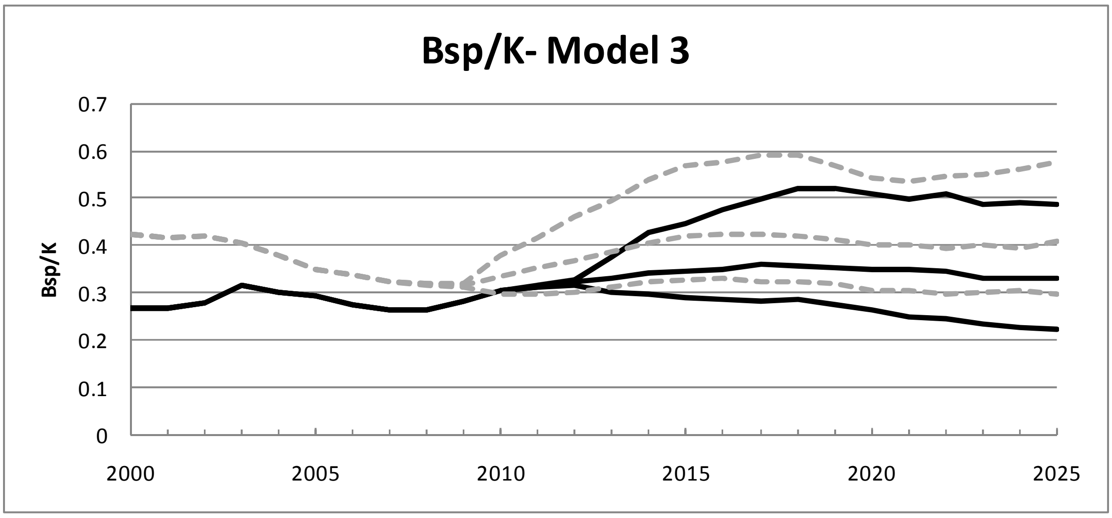


Figure 3b: Comparison of the Model 3 spawning biomass relative to K (B_{sp}/K) median trajectory with 5th and 95th percentiles predicted under OMP-2008 (grey dashed lines) and the re-tuned OMP-2010 (black solid lines).



Appendix: Effort values for each area along with the estimated $\bar{E}$ values of the effort saturation operating model.

Figure A1: Effort (catch/cpue) values shown along with the estimated $\bar{E}$ values from the effort saturation operating model (shown as the solid line).