Initial OMP results for the South Coast Rock Lobster Resource OMP

S.J. Johnston and D.S. Butterworth.

Introduction

Some initial results following the development of an OMP framework for the management of South Coast rock lobster are presented here, corresponding to a constant catch scenario and runs of a CPUE-tuned-based feedback control rule.

First though, the assumptions made for the OMP testing are listed below.

Assumptions required for future projections for OMP testing

Summary of current assessments (note 2005 refers to the 2005/6 season):

- Fit to CPUE and CAL data up to and including 2005
- The assessment includes observed catches for 2006; thus the assessment ended at the start of 2007 i.e. projections start at beginning of 2007
- However the 2007 catch is now known
- The OMP thus needs to sets its first OMP TAC for 2008
- The OMP will use model-generated CPUE from 2006
- The OMP TAC for year *y* will use CPUE data from 1974 - (*y*-2), and catches from 1973 to (*y*-1).

In programming terms, the population projection commences at the start of 2006, though with fixed catches until these are first set by the OMP in 2008.

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 1998+ $$R_y = \frac{\alpha B_y^{sp}}{\beta + (B_y^{sp})} e^{\varepsilon_y} \qquad \varepsilon_y \sim N(0, \sigma_R^2) \qquad (1)$$

where σ_R =0.4

The assessment provides values for $\hat{N}_{2007,a}$ for $a \geq 1$, under the assumption that $\varepsilon_y = 0$ for 1998+. To allow for generated ε_y from 1998 to 2006, the following adjustment is made to the numbers at age to start the projections:

$$\hat{N}_{2007,a} \rightarrow \hat{N}^*_{2007,a} e^{\varepsilon_{2007-a}} \qquad \text{for } a = 1,2...7 \qquad (2)$$

This does not introduce any substantial bias into computations, as any catch prior to 2007 from the cohorts concerned is minimal.

However, given indications of some serial correlation in the plots in Figure 3 of WG/05/08/SCL17, an AR(1) needs to be considered.

To estimate the associated serial correlation s_R:

$$s_R = \sum_{y=1974}^{1996} \hat{\varepsilon}_{y+1}\hat{\varepsilon}_y \Big/ \sum_{y=1974}^{1996} \hat{\varepsilon}_y^2 \tag{3}$$

Then to generate instead of ε_y from $N(0,\sigma_R^2)$, use

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

This equation is first applied for y=1997 to get ε_{1998}^y with an input of $\varepsilon_{1997}^s = \hat{\varepsilon}_{1997}$, i.e. the value estimated in the assessment.

2. Proportional split of recruitment R_y by Area

For each Area A $\lambda_y^{*,A}$ has been estimated from **1973** to **2000**

$$R_y^A = \lambda_y^{*,A} R_y \tag{5}$$

where

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

and

$$\varepsilon_{A,y} \sim N(0,\sigma_\lambda^2); \qquad \sigma_\lambda = 0.05. \text{ (ie add a penalty function)}$$

The $\varepsilon_{A,y}$ are thus further estimable parameters (besides the three λ^A parameters).

From these $\varepsilon_{A,y}$ estimated values, $\bar{\varepsilon}_A$ and σ_ε^A (the mean and standard deviation) can be calculated.

For 2001+, $\lambda_y^{*,A,s}$ must be generated

and for each year, $\lambda_y^{*,A,s} \rightarrow \dfrac{\lambda_y^{*,A,s}}{\sum_{A=1}^{3} \lambda_y^{*,A,s}}$ for normalisation (7)

where s is the simulation index. The $\lambda_y^{*,A,s}$ are generated from $\hat{\lambda}^A e^{\varepsilon_y^{A,s}}$, where

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

This is effected by updating equation (2) as follows:

$$N_{2007,a}^A \rightarrow \hat{N}_{2007,a} e^{\varepsilon_{2007-a}} \lambda_{2007-a}^{*A,s} \qquad \text{for } a = 1,2,3,4 \text{ (i.e. } \lambda \text{ generated)} \tag{8}$$

$$\rightarrow \hat{N}_{2007,a} e^{\varepsilon_{2007-a}} \hat{\lambda}_{2007-a}^A \qquad \text{for a = 5,6,7 (i.e. } \lambda \text{ as estimated in assessment)}$$

For projections, first get $s_\lambda^A = [\sum_{y=1974}^{1999} \hat{\varepsilon}_{A,y+1}\hat{\varepsilon}_{A,y}] / \sum_{y=1974}^{1999} \hat{\varepsilon}_{A,y}^2$, (9)

$$\sigma_{\lambda}^{A} = \sqrt{[\sum_{y=1974}^{2000} \hat{\varepsilon}_{A,y}^{2}]/(2000-1974+1)} \qquad (10)$$

3 Selectivity

<u>MARAM selectivity models (Model 3)</u>

Model 3 estimates $\delta_y^{m/f,A}$ for **1994** to **2005** (see Johnston and Butterworth (2008a) Equation 24 reproduced below as Equation 11).

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

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

Thus for 2006+ $\qquad \delta_y^{m/f,A,s} = \bar{\delta}^{m/f,A} + \eta_y^{m/f,A,s}$ $\qquad$ (12)

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

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

where the serial correlation $\qquad s_{\delta}^{m/f,A} = \left[\sum_{y=1994}^{2004}\hat{\eta}_{y+1}\hat{\eta}_y\right] / \sum_{y=1994}^{2004}\hat{\eta}_y^2$ $\qquad$ (14)

and where $\bar{\delta}^{m/f,A}$ and $\sigma_{\delta}^{m/f,A}$ are calculated as the mean and standard deviation of the 1994 to 2005 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 7 of Johnston and Butterworth (2008b),
$S2_l^{m/f,3} = e^{-\left(l-l_{m/f}^{*}\right)^2/\omega^2}$	(the second normal-shaped selectivity function which remains fixed over time), and
μ	remains constant in the future at the estimated value.

OLRAC selectivity models (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 for **1973-2005**.

The estimates of past values show strong serial 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 2006+ $$x_y^{m/f,A,s} = \bar{x}^{m/f,A} + \eta_y^{m/f,A,s} \tag{22}$$

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 serial correlation $$s_x^{m/f,A} = \left[\sum_{y=1973}^{2004}\hat{\eta}_{y+1}\hat{\eta}_y\right] / \sum_{y=1973}^{2004}\hat{\eta}_y^2 \tag{24}$$

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 2005 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 CPUE values for simulation *s* are generated for each area A from:

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

At a later stage, future catch-at-length data may also be generated to allow for testing of the possible use of such data inputs to the OMP as well.

TAC rule for initial OMP testing

First a simple rule based on recent CPUE trends is implemented, *viz.*

$$TAC_{y+1} = TAC_y (1 + \alpha s_y^A) \tag{26}$$

where

s_y^A is the slope parameter from a regression of $\ln CPUE_y^A$ versus y over the last five years 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.

A rule to control the inter-annual TAC variation of no more than 10% up or down from year to year is applied.

The average areal split over the last five years is assumed to apply without change for each year in the future.

Summary statistics

Results reported are the median and 5th and 95th percentiles of 100 simulations for the following statistics:

<u>Average Catch</u>

C_{ave}^5 = average catch (all areas combined) over the 2008-2012 period

C_{ave}^{10} = average catch (all areas combined) over the 2008-2017 period

C_{ave}^{15} = average catch (all areas combined) over the 2008-2022 period

<u>Average annual catch variation</u>

V^5 = average inter-annual catch variation (expressed as a percentage) over the 2008-2012 period

V^{10} = average inter-annual catch variation (expressed as a percentage) over the 2008-2017 period

V^{15} = average inter-annual catch variation (expressed as a percentage) over the 2008-2022 period

Spawning biomass 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 to date

Results presented here are generated using Model 3 of WG/05/08/SCRL17 (new catch series, MARAM time-varying selectivity, no catch down-weighting) as the underlying operating model.

Table 1 reports the serial correlation estimates for Model 3 for the stock recruit residuals (see Equation (3)), the $\lambda_y^{*,A}$ values (see Equation (9)), and for the selectivity $\delta^{m/f,A}$ values (see Equation (15)).

Figures 1-3 show the model projected values (for the first three simulations) of the stock recruit residuals (Figure 1), the $\lambda_y^{*,A}$ values (Figure 2) and the selectivity delta values (Figure 3).

Table 2 reports the performance statistics for a constant catch projection (at the current TAC level of 382 MT) into the future, as well as for some initial OMP candidates. Figure 4 shows the associated median spawning biomass trajectories with their 5th and 95th percentiles for the CC scenario. Figure 5 shows future TAC trajectories for one of the OMP candidiates.

Immediate future work priorities

Repeat calculations shown for Model 4 (OLRAC time-varying selectivity) and Model 5 (effort saturation).

Feedback is requested in particular on priorities for outputs desired for reporting. For example, would future effort and CPUE projections be of interest?

Table 1: Serial correlation values for the operating model Model 3.

	Serial correlation
Stock recruit s_R	0.322
s_λ^1	0.589
s_λ^2	0.415
s_λ^3	0.517
$s_\delta^{m,1}$	0.353
$s_\delta^{f,1}$	0.463
$s_\delta^{m,2}$	0.889
$s_\delta^{f,2}$	0.382
$s_\delta^{m,3}$	0.025
$s_\delta^{f,3}$	0.304

Table 2: Summary performance statistics for the CC=382 MT scenario and a number of OMP candidates. Medians with 5th and 95th percentile are reported.

Performance statistic	CC = 382 MT	OMP α = 0.5	OMP α = 1	OMP α =2
C_{ave}^5	382 [382; 382]	373 [362; 386]	363 [344; 390]	348 [315; 398]
C_{ave}^{10}	382 [382; 382]	377 [361; 397]	373 [342; 407]	362 [321; 423]
C_{ave}^{15}	382 [382; 382]	381 [358; 405]	379 [340; 421]	367 [314; 438]
V^5	0 [0; 0]	1.1 [0.6; 1.9]	2.2 [1.2; 3.8]	4.2 [2.4; 6.8]
V^{10}	0 [0; 0]	1.2 [0.7; 2.3]	2.4 [1.4; 3.8]	4.4 [2.9; 6.2]
V^{15}	0 [0; 0]	1.2 [0.9; 1.6]	2.3 [1.4; 3.5]	4.3 [2.6; 5.5]
B^{sp} (2015/2006)	1.16 [0.84; 1.60]	1.16 [0.88; 1.58]	1.17 [0.88; 1.58]	1.20 [0.90; 1.60]
B^{sp} (2025/2006)	1.07 [0.66; 1.60]	1.10 [0.72; 1.56]	1.09 [0.74; 1.59]	1.13 [0.74; 1.64]

Figure 1: Stock recruit residuals projected into the future for the first 3 simulations, compared with those estimated for the 1990 to 1997 period. The vertical line shows the start of the period for which SR residuals are generated for each simulation.

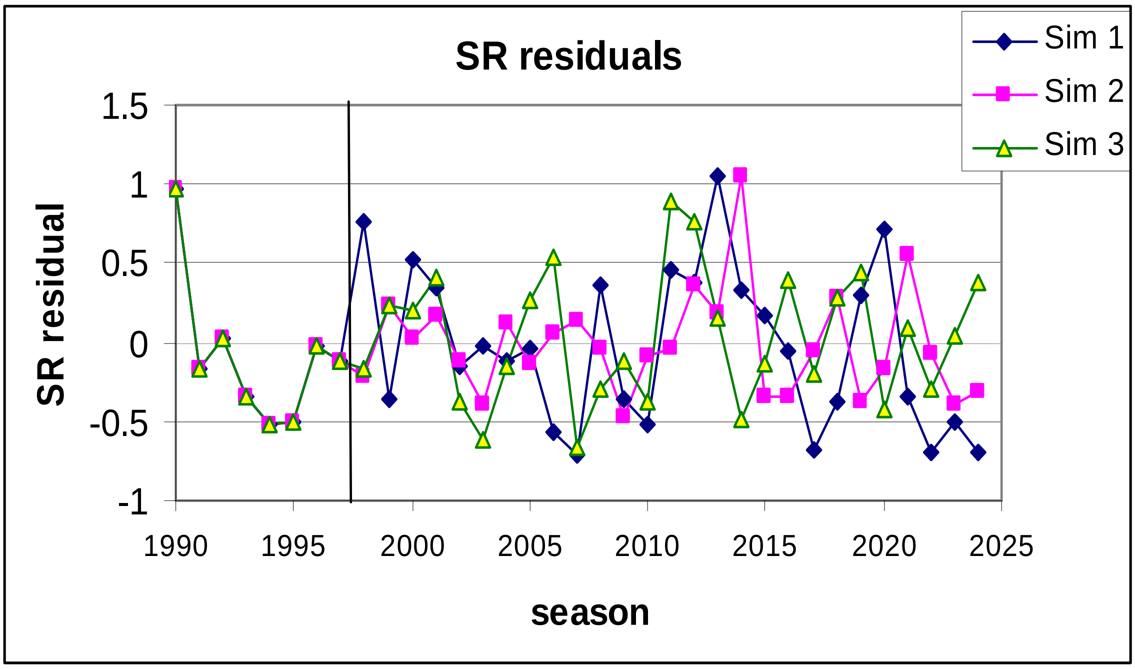

Figure 2: $\lambda_y^{*,1}$ residuals for Area 1 projected into the future for the first 3 simulations, compared with those estimated for the 1975-2000 period. The vertical line shows the start of the period for which the values are generated in each simulation.

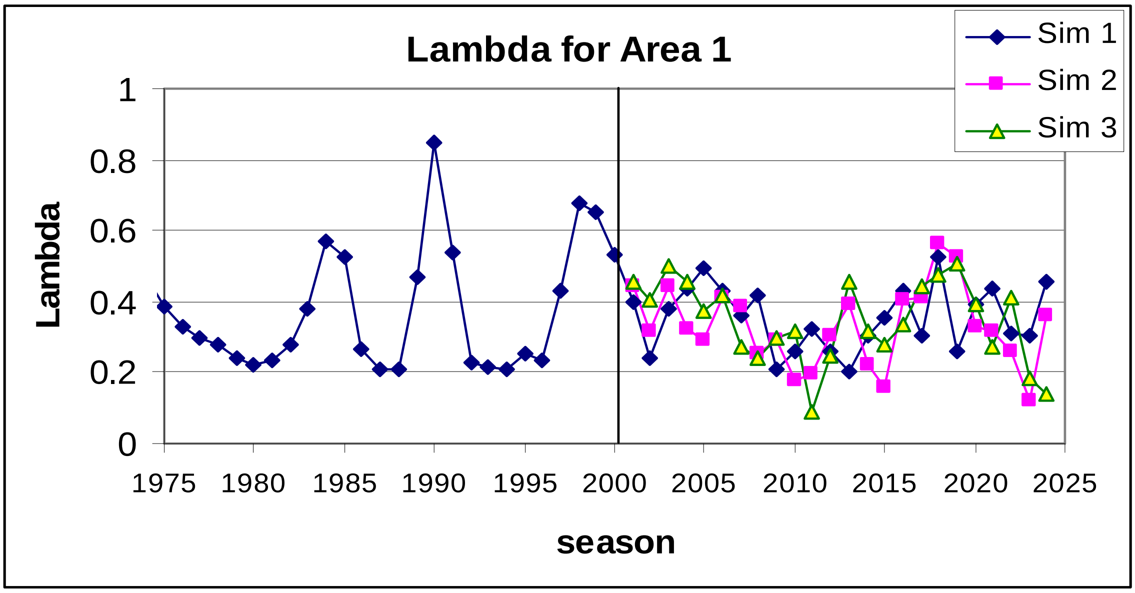

Figure 3: Selectivity $\delta_y^{m,1}$ residuals for Area 1 projected into the future for the first 3 simulations, compared with those estimated for the 1994 to 2005 period. The vertical line shows the start of the period for which the values are generated in each simulation.

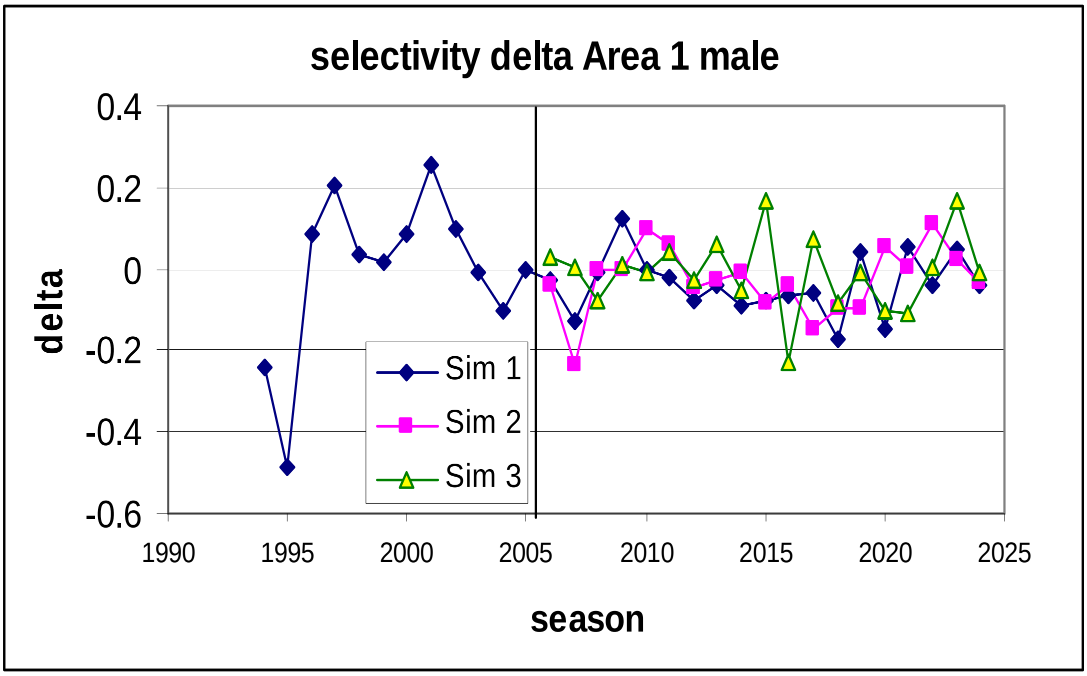

Figure 4a: *B*sp (spawning biomass in MT) trajectory for a future constant catch of 382 MT (median and 90% PI shown) for operating Model 3.

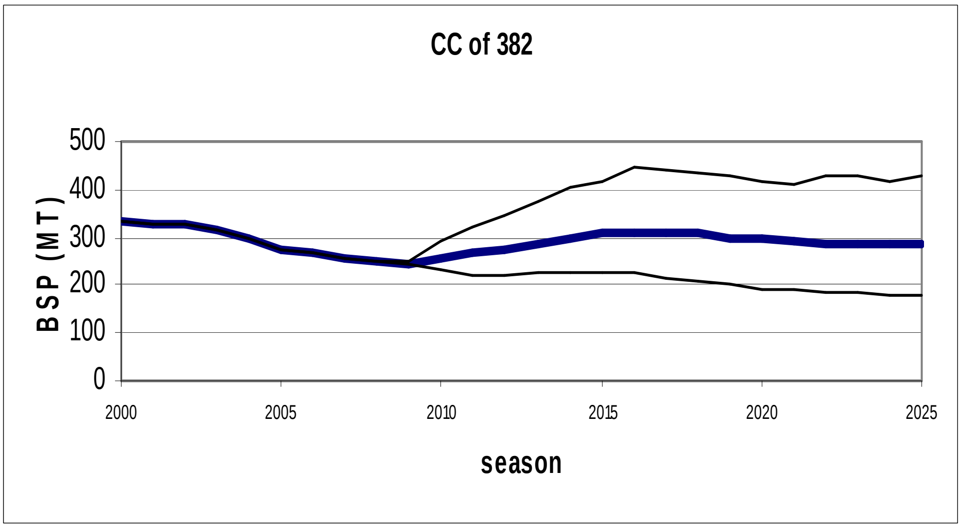

Figure 4b: Upper 95%ile plots of *B*sp (spawning biomass in MT) trajectories for three OMP variants (operating Model 3).

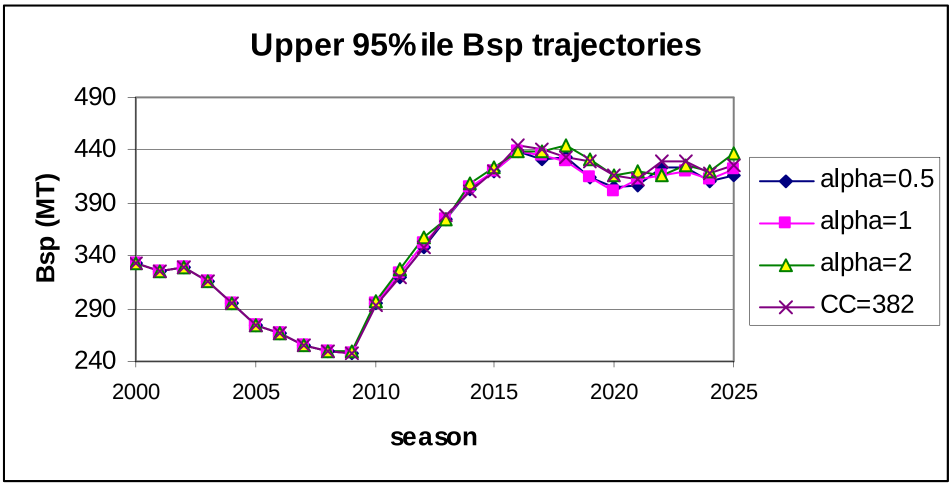

Figure 4c: Median plots of *B*sp (spawning biomass in MT) trajectories for three OMP variants (operating Model 3).

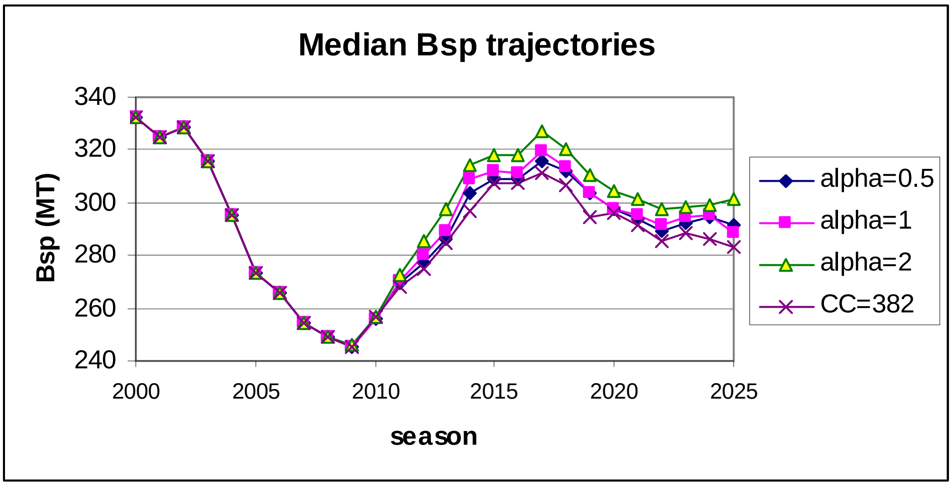

Figure 4d: Lower 5%ile plots of *B*sp (spawning biomass in MT) trajectories for three OMP variants (operating Model 3).

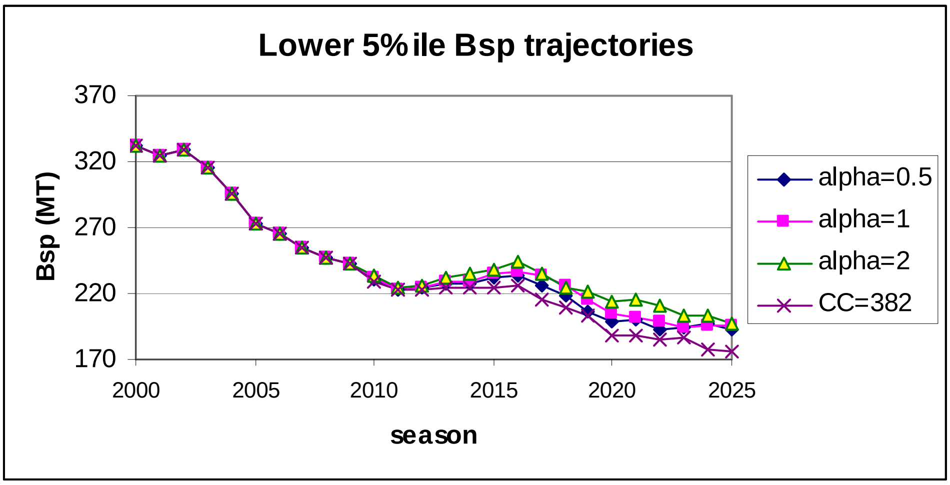

Figure 5a: TAC (MT) trajectory for the OMP α =1 candidate (median and 90% PI shown) for operating Model 3.

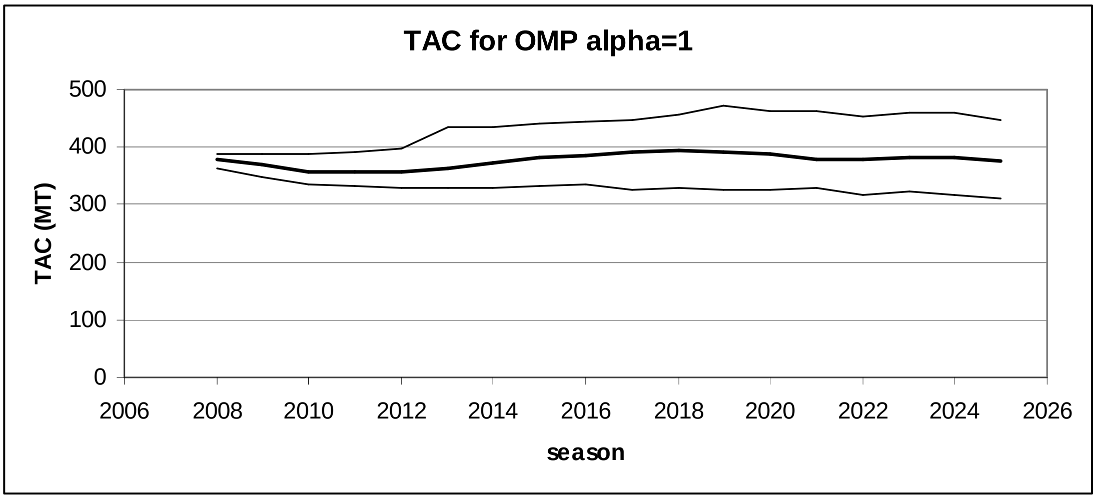

Figure 5b: TAC trajectories for the first 5 simulations for OMP alpha=1.