SCRL OMP-2014 simulation testing

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SUMMARY

This document sets out the details of the process used for projecting forward and generating future pseudo-data in the simulation testing process used in the process culminating in the adoption of the current SCRL OMP.

Introduction

The simulation framework for the final OMP-2014 testing is described below. The Operating Model (OM) corresponds to the 2013 assessment; this OM was used in the simulation testing of OMP-2014 (although this assessment has subsequently been updated each year).

As in 2010 for the OMP developed then, 100 simulations of the operating model were projected ahead under TACs calculated using the OMP rules. Each simulation had random noise added to certain components of the model (the selectivity and the recruitment) in the future, and generated input data (CPUE), as described below. The simulation method was identical to that used in 2010. This included the assumption that in the forward projections of the simulations, the split of the global TAC between the three fishing sub-areas was assumed to be proportional to the recent (here now 2007-2011) average fishing mortalities in each sub-area.

In summary the 2013 updated assessment (OM) used in OMP testing:

- Fit to CPUE and CAL data up to and including 2010
- The assessment included the observed catch for 2011 and assumed the catch for the 2012 season equal the TAC for 2012 season; thus the assessment ended at the start of 2012, i.e. projections started at the beginning of 2013.

Thus:

- The OMP consequently needed to sets its first OMP TAC for 2013
- The OMP used the observed CPUE for 2004-2010, and then model-generated CPUE (with noise) for 2011+
- The OMP TAC for year *y* used CPUE information from 2003 to year (*y*-2), and catches from 1973 to year (*y*-1), so as to incorporate only the information which would be available at the time the TAC has to be recommended.

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

Stock-Recruit residuals

The model had already estimated residuals for 1974-2003[1].

For 2004+ $$R_y = \frac{\alpha B_y^{sp}}{\beta + B_y^{sp}} e^{\varepsilon_y - \sigma_R^2/2} \quad \varepsilon_y \sim N(0, \sigma_R^2) \tag{1}$$

where σ_R =0.8

The assessment provides values for $\hat{N}_{2013,a}$ for $a \geq 1$, under the assumption that ε_y are estimated for 1974-2003 (but constrained to average zero) and fixed at 0.0 for 2004+. To allow for random variation in recruitment from 2004 to 2012 when projecting, the following adjustments are made to the numbers at age to start the projections:

$$\hat{N}_{2013,a} \to \hat{N}_{2013,a} e^{\varepsilon_{2013-a}} \quad \text{for } a = 1,2...7 \tag{2}$$

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 2013 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:

$$s_R = \sum_{y=1974}^{2002} \hat{\varepsilon}_{y+1} \hat{\varepsilon}_y \,/\, \sum_{y=1974}^{2002} \hat{\varepsilon}_y^2 \tag{3}$$

Then instead of generating the ε_y from $N(0, \sigma_R^2)$, the following equation is used:

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

This equation is first applied for *y*=2004 to provide ε_{2004}^y with an input of $\varepsilon_{2003}^s = \hat{\varepsilon}_{2003}$, i.e. the value estimated in the assessment.

Proportional split of recruitment R_y by sub-area

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

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

[1] Residuals cannot be estimated for further years because the signal of recruitment strength comes from the length structure of the catch, and lobsters are first taken by the fishery only at about age 8-10 years.

where

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

and

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

has been estimated from **1973** to **2003**

The historical 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 log-likelihood related to the assumption that they are normally distributed.

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

$$s_\lambda^A = [\sum_{y=1973}^{2002} \hat{\varepsilon}_{A,y+1}\hat{\varepsilon}_{A,y}] / \sum_{y=1973}^{2002} \hat{\varepsilon}_{A,y}^2 \ , \tag{7}$$

$$\sigma_\lambda^A = \sqrt{[\sum_{y=1973}^{2003} \hat{\varepsilon}_{A,y}^2]/(2003-1973+1)} \tag{8}$$

For 2004+, $\lambda_y^{*,A,s}$ need to be generated where for each year:

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

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:

$$N_{2013,a}^A \to \hat{N}_{2013,a} e^{\varepsilon_{2010-a}} \lambda_{2013-a}^{*A,s} \qquad \text{for } a = 1,2,3,4 \text{ (i.e. } \lambda \text{ generated)} \tag{10}$$

$$\to \hat{N}_{2013,a} e^{\varepsilon_{2010-a}} \hat{\lambda}_{2013-a}^{A} \qquad \text{for } a = 5,6,7 \text{ (i.e. } \lambda \text{ as estimated in assessment)}$$

Future split of catch between sub-areas

For 2012+, the total TAC for each season is split between the three sub-areas as follows:

$$C_y^A = C_y^T \frac{\bar{F}^A B_{exp,y}^A}{(\bar{F}^{A1E} B_{exp,y}^{A1E} + \bar{F}^{A1W} B_{exp,y}^{A1W} + \bar{F}^{A2+3} B_{exp,y}^{A2+3})} \tag{11}$$

where

$$\bar{F}^A = \frac{\sum_{y=2007}^{y=2011} F_y^A}{5} \tag{12}$$

Selectivity

The RC model assumes constant selectivity for sub-areas A1E and A1W but time-varying selectivity for A2+3. The selectivity function is:

$$S_{y,l}^{m/f,A} = \frac{e^{-\mu^{m/f,A}.l}}{1+e^{(-\delta^{m/f,A}(l-l_*^{m/f,A})}} \tag{13}$$

Thus there are three estimable parameters for each sex and each area (μ, δ and l*).

For Area A1E and A1W – selectivity is assumed to remain constant over time.

For Area A2+3 selectivity is allowed to vary over time for the period for which there are catch-at-length data (1995-2010).

Thus for y=1995, 2010:

$$l_*^m \rightarrow l_*^m + \varepsilon_{l*,y}^m \qquad \varepsilon_{l*,y}^m \sim N(0, \sigma_{l*,m}^2)$$

$$l_*^f \rightarrow l_*^f + \varepsilon_{l*,y}^f \qquad \varepsilon_{l*,y}^f \sim N(0, \sigma_{l*,f}^2)$$

$$\mu^m \rightarrow \mu^m + \varepsilon_{\mu,y}^m \qquad \varepsilon_{\mu,y}^m \sim N(0, \sigma_{\mu,m}^2)$$

$$\mu^f \rightarrow \mu^f + \varepsilon_{\mu,y}^f \qquad \varepsilon_{\mu,y}^f \sim N(0, \sigma_{\mu,f}^2)$$

$$\delta^m \rightarrow \delta^m + \varepsilon_{\delta,y}^m \qquad \varepsilon_{\delta,y}^m \sim N(0, \sigma_{\delta,m}^2)$$

$$\delta^f \rightarrow \delta^f + \varepsilon_{\delta,y}^f \qquad \varepsilon_{\delta,y}^f \sim N(0, \sigma_{\delta,f}^2)$$

For future stochastic projections, the six parameters above are assumed to change from year to year as an AR1 process.

Thus for 2011+: $\delta_y^{m/f,A,s} = \bar{\delta}^{m/f,A} + \eta_y^{m/f,A,s}$ (14)

where $\eta_{y+1}^{m/f,A,s} = s_\delta^{m/f,A} \eta_y^{m/f,A,s} + \sqrt{1-s_\delta^{m/f,A^2}}\, \chi_y^s$ (15)

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

where the auto-correlation $$s_\delta^{m/f,A} = \left[\sum_{y=1995}^{2009} \hat{\eta}_{y+1}\hat{\eta}_y\right] / \sum_{y=1995}^{2009} \hat{\eta}_y^2 \tag{16}$$

and where $\bar{\delta}^{m/f,A}$ and $\sigma_\delta^{m/f,A}$ are calculated as the mean and standard deviation of the estimates for 1995 to 2010.

The other parameters are treated in a similar manner.

Allowing for fleet movement if CPUE in an area is too small to be economically viable

Following a task group meeting, OLRAC (pers. commn) provided the data showing the percentage of total SCRL effort from each sub-area against the catch (kg tails) per day for that area. This plot suggested that industry would move out of an area if catch rates dropped below 180 kg tails per day. Rules reported in Table 1 were developed on this basis for use of splitting the total TAC between the three sub-areas. **Note that these rules are for simulation purposes only, and that no regulation of TAC at a sub-area level is recommended. A number of scenarios were initially examined in simulation testing.**

Taking account of the TAE restriction

The total TAC for the resource set using the OMP is TAC_y. An average of the "observed" CPUEs (weighted average of cpue values for three areas) over y-2, y-3 and y-4 period) is denoted by $\overline{CPUE}$. The threshold CPUE, $CPUE_{thresh} = \frac{\overline{CPUE}}{D} = \frac{\overline{CPUE}}{1.555} =$ where the value of D (1.555) is as used in the OLRAC TAE calculations (OLRAC cc 2011).

During the simulations, $CPUE_y$ is generated from operating model including error. Then:

$$\begin{aligned} &\text{IF } CPUE_y > CPUE_{thresh} && TAC_y \rightarrow TAC_y \\ &\text{IF } CPUE_y \leq CPUE_{thresh} && TAC_y \rightarrow TAC_y * \frac{CPUE_y}{CPUE_{thresh}} \end{aligned} \tag{17}$$

so that the TAE limitation is respected.

Future data generation

Future CPUE values need to be generated. There are always model estimates 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 sub-area. Future (2011+) CPUE values for simulation *s* are generated for each sub-area A from:

$$CPUE_y^{A,s} = CP\hat{U}E_y^{A,s} \exp(\varepsilon_y^{A,s}) \qquad \varepsilon_y^{A,s} \sim N(0,(\sigma_{CPUE}^A)^2)) \tag{18}$$

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

Robustness testing

For reasons of time, robustness testing was restricted to checking sensitivity to the fleet movement model.

Summary Statistics

Note that the units of the target CPUE are "GLM-standardised" units. A calibration coefficient of 259 is used to convert the CPUE target into tails kg per day, which is more meaningful to the industry. Output statistics reported are:

- $CPUE_{targ}$: Catch per unit effort in GLM units (kgs per trap)
- $CPUE_{targ}$ in industry units: $CPUE_{targ}$ x 259 (units are kg tails per day)
- CPUE threshold: the CPUE level (in industry units) in a sub-area below which it is assumed in the projections that catches are transferred out of that sub-area to the other sub-areas.
- CPUE(2025): the median estimated CPUE in 2015.
- Bsp(2025/2006): the spawning biomass in 2025 relative to 2006 (this values was used to tune the different OMP candidates).
- Bsp(2025/K): the spawning biomass in 2025 relative to the unfished (pristine) spawning biomass.
- Cave(2014-2025): the average catch over the 2014-2025 period.
- AAV: the average (over 2014-2015) inter-annual catch variation (expressed as %). Note that all OMPs considered assumed a maximum inter-annual TAC change constraint of 5%.
- $B^{exp}(2025)/K$: the exploitable biomass in 2025 relative to the unfished pristine exploitable biomass (reported for each sub-area).
- Effort(2025/2014): the effort in 2025 relative to the effort in 2014.
- CPUE(2025): the median estimated CPUE in 2025.

- Effort(2025/2014): the effort in 2025 relative to the effort in 2014. Here effort is simply calculated as “Catch/CPUE”.
- Size structure of the catch in 2014 and 2015. These were reported to see if there is a change in the expected catch size composition over time. Size structures were reported for each sub-area individually. The catch proportions for each size class were averaged over the 1000 simulations, and the male and female proportions were summed.

Reference

OLRAC cc, 2011. Methodology for effort control in the South Coast rock lobster fishery. FISHEREIS/2011/AUG/SWG/SCRL/05.

Table 1. Rules for shifting TAC in areas where catch rates are below 180 kg tails per day (for simulation purposes).

Senario	CPUE_ind (y-1) (kg tails per day)			Catch (y+1)		
	A1E	A1W	A23	A1E	A1W	A23
1	<=180	<=180	<=180	0	0	0
2	<=180	<=180	>180	0	0	A1E+A1W+A23
3	<=180	>180	<=180	0	A1E+A1W+A23	0
4	<=180	>180	>180	0	A1W+($A1E * \frac{A1W}{A1W+A23}$)	A2+3+($A1E * \frac{A23}{A1W+A23}$)
5	>180	<=180	<=180	A1E+A1W+A23	0	0
6	>180	>180	>180	A1E	A1W	A2+3
7	>180	<=180	>180	A1E+($A1W * \frac{A1E}{A1E+A23}$)	0	A2+3+($A1W * \frac{A23}{A1E+A23}$)
8	>180	>180	<=180	A1E+($A23 * \frac{A1E}{A1E+A1W}$)	A1W+($A23 * \frac{A1W}{A1E+A1W}$)	0