Final 2013 updated South Coast Rock Lobster assessment results and description of OMP simulation framework

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Results presented in FISHERIES/2013/MAY/SWG-SCL/03 contained a slight error in that the recruitment residuals are required to be adjusted by $\sigma_R^2/2$ as shown below:

$$R_y = \frac{\alpha B_y^{sp}}{\beta + B_y^{sp}} e^{\varepsilon_y - \sigma_R^2/2} \quad \text{where} \tag{1}$$

$\varepsilon_y \sim N(0, \sigma_R^2)$ and σ_R= 0.8

Results in this document have taken this adjustment into account. Note also that the model N5 that was presented in FISHERIES/103/May/SWG-SCRL/03 is assumed as the Reference Case (RC1) model for the results presented here.

Summary of stock-recruitment function residuals in assessment

The assumption that these residuals are log-normally distributed (and could be serially correlated) defines a corresponding joint prior distribution. This can be equivalently regarded as a penalty function added to the log-likelihood, which for fixed serial correlation ρ is given by:

$$-\ln L = -\ln L + \sum_{y=y1}^{y2} \left[\frac{\varepsilon_y - \rho\varepsilon_{y-1}}{\sqrt{1-\rho^2}} \right]^2 / 2\sigma_R^2 \tag{2}$$

where

$\varsigma_y = \rho\tau_{y-1} + \sqrt{1-\rho^2}\varepsilon_y$ is the recruitment residual for year y ,

$\varepsilon_y \sim N(0, \sigma_R^2)$,

σ_R is the standard deviation of the log-residuals, which is input,

ρ is their auto-correlation coefficient, and

y1=1974 and *y2*=2003 here.

Note that here , ρ is set equal to zero, i.e. the recruitment residuals are assumed uncorrelated, and σ_R is set equal to 0.8. Recruitment residuals are estimated for years 1974 to 2003 only, and are set equal to zero after this year.

The following term is added to constrain the size of these terms (i.e. to fit to genuine difference rather than to noise) and to force the average of the residuals to equal zero:

$$-\ln L = \ln L + W[\sum_{1974}^{2003} \frac{\varepsilon_y}{\sigma_R}]^2 \qquad (3)$$

where the weighting factor *W* is set high to ensure that the sum above ends as zero. This is to ensure that when projecting, the stock-recruitment curve used more closely reflects the past patterns of recruitment and its variability.

Projection assumptions: Deterministic

Future recruitment

The model estimates residuals for 1974-2003. For 2004+ recruitment is set equal to its expected values given the fitted stock-recruit relationship to provide mean unbiased results. The relationship itself is $R_y = \frac{\alpha B_y^{sp}}{\beta + B_y^{sp}} e^{\varepsilon_y - \sigma_R^2/2}$ where $\varepsilon_y \sim N(0, \sigma_R^2)$ and $\sigma_R = 0.8$. This means that the expected recruitment $E[R_y] = \frac{\alpha B_y^{sp}}{\beta + B_y^{sp}}$

Proportional split of recruitment R_y by Area

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

$$R_y^A = \lambda_y^{*,A} R_y \qquad (4)$$

where

$$\lambda_y^{*,A} = \frac{\lambda^A e^{\varepsilon_{A,y}}}{\sum_A \lambda^A e^{\varepsilon_{A,y}}} \qquad (5)$$

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

For 2004+, the average $\lambda_y^{*,A}$ over 1973-2003 is used for each area A.

Future selectivity:

For A2+3, selectivity for 2011+ is assumed to be fixed at the estimated selectivity for 2010. Continue to assume time-invariant selectivity for A1E and A1W.

Future split of catch between areas

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

$$C_y^A = C_y^T \frac{\bar{F}^A B_{exp,y}^A}{(\bar{F}^{A1E} B_{exp,y}^{A1E} + \bar{F}^{A1W} B_{exp,y}^{A1W} + \bar{F}^{A2+3} B_{exp,y}^{A2+3})} \quad (6)$$

where

$$\bar{F}^A = \frac{\sum_{y=2007}^{y=2011} F_y^A}{5} \quad (7)$$

Simulation Testing of OMP-2013

The stochastic simulation framework is the same as previously (see FISHERIES/2010/JUL/SWG-SCRL/12).

As in 2010, 100 simulations of each operating model projected ahead under TACs calculated using the retuned OMP will be calculated. Each simulation will have 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 2010. This includes the assumption that in the forward projections of the simulations the split of the global TAC between the three fishing areas is assumed to be proportional to the recent (2007-2011) average fishing mortalities in each area.

Summary of 2013 updated assessments (OMs):

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

Thus:

- The OMP thus needs to sets its first OMP TAC for 2013
- The OMP uses the observed CPUE for 2004-2010, and then model-generated CPUE (with noise) for 2011+

- 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 needs to be made for the operating models to be used. The framework adopted for these is as follows.

1. Stock-Recruit residuals

The model had already estimated residuals for 1974-2003.

For 2004+ $$R_y = \frac{\alpha B_y^{sp}}{\beta + B_y^{sp}} e^{\varepsilon_y - \sigma_R^2/2} \quad \varepsilon_y \sim N(0,\sigma_R^2) \qquad (8)$$

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:

$$\hat{N}_{2013,a} \rightarrow \hat{N}_{2013,a} e^{\varepsilon_{2013-a}} \quad \text{for } a = 1,2...7 \qquad (9)$$

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:

$$s_R = \sum_{y=1974}^{2002} \hat{\varepsilon}_{y+1} \hat{\varepsilon}_y \Big/ \sum_{y=1974}^{2002} \hat{\varepsilon}_y^2 \qquad (10)$$

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

$$\varepsilon_{y+1}^s = s_R \varepsilon_y^s + \sqrt{1-s_R^2}\,\eta_y^s \qquad \eta_y^s \sim N(0,\sigma_R^2). \qquad (11)$$

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.

2. Proportional split of recruitment R_y by Area

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

$$R_y^A = \lambda_y^{*,A} R_y \tag{12}$$

where

$$\lambda_y^{*,A} = \frac{\lambda^A e^{\varepsilon_{A,y}}}{\sum_A \lambda^A e^{\varepsilon_{A,y}}} \tag{13}$$

and

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

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

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:

$$s_\lambda^A = [\sum_{y=1973}^{2002} \hat{\varepsilon}_{A,y+1}\hat{\varepsilon}_{A,y}] / \sum_{y=1973}^{2002} \hat{\varepsilon}_{A,y}^2 \ , \tag{14}$$

$$\sigma_\lambda^A = \sqrt{[\sum_{y=1973}^{2003} \hat{\varepsilon}_{A,y}^2]/(2003-1973+1)} \tag{15}$$

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

$$\lambda_y^{*,A,s} \rightarrow \frac{\lambda_y^{*,A,s}}{\sum_{A=1}^{3} \lambda_y^{*,A,s}} \qquad \text{so that proportions sum to 1} \tag{16}$$

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:

$$N_{2013,a}^{A} \to \hat{N}_{2013,a} e^{\varepsilon_{2010-a}} \lambda_{2013-a}^{*A,s} \qquad \text{for } a = 1,2,3,4 \text{ (i.e. } \lambda \text{ generated)} \tag{17}$$

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

3 Selectivity

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

$$S_{y,l}^{m/f,A} = \frac{e^{-\mu^{m/f,A}.l}}{1+e^{(-\delta^{m/f,A}(l-l_*^{m/f,A})}} \tag{18}$$

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:

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

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

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

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

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

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

For future stochastic projection, the above six parameter values are assumed to change from year to year as an AR1 process.

Thus for 2011+: $\delta_y^{m/f,A,s} = \bar{\delta}^{m/f,A} + \eta_y^{m/f,A,s}$ (19)

where $\eta_{y+1}^{m/f,A,s} = s_\delta^{m/f,A} \eta_y^{m/f,A,s} + \sqrt{1 - s_\delta^{m/f,A^2}} \chi_y^s$ (20)

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

where the auto-correlation $$s_\delta^{m/f,A} = \left[\sum_{y=1995}^{2009} \hat{\eta}_{y+1}\hat{\eta}_y\right] / \sum_{y=1995}^{2009} \hat{\eta}_y^2 \qquad (21)$$

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 2010 estimates.

The other parameters are treated in a similar manner.

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 (2011+) CPUE values for simulation *s* are generated for each area A from:

$$CPUE_y^{A,s} = CP\hat{U}E_y^{A,s} \exp(\varepsilon_y^{A,s}) \qquad \varepsilon_y^{A,s} \sim N(0,(\sigma_{CPUE}^A)^2)) \qquad (22)$$

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

TAC rule for OMP testing

OMP 2010 consists of an algorithm that calculates the TAC for the resource using CPUE data collected from each of three areas (Areas 1, 2 and 3). OMP 2010 is now updated slightly to reflect the change to areas A1E, A1W and A2+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 2013 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 2011.

TAC setting algorithm

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

$$TAC_{y+1} = TAC_y[1+\alpha(s_y - \delta)]h(r_y) \qquad (23)$$

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

$$s_y = \sum_{A=1}^{3} w^A s_y^A \qquad (24)$$

where $$w^A = \frac{\frac{1}{\sigma_S^{A^2}}}{\sum_{A'=1}^{3}\left(\frac{1}{\sigma_S^{A'^2}}\right)} \qquad (25)$$

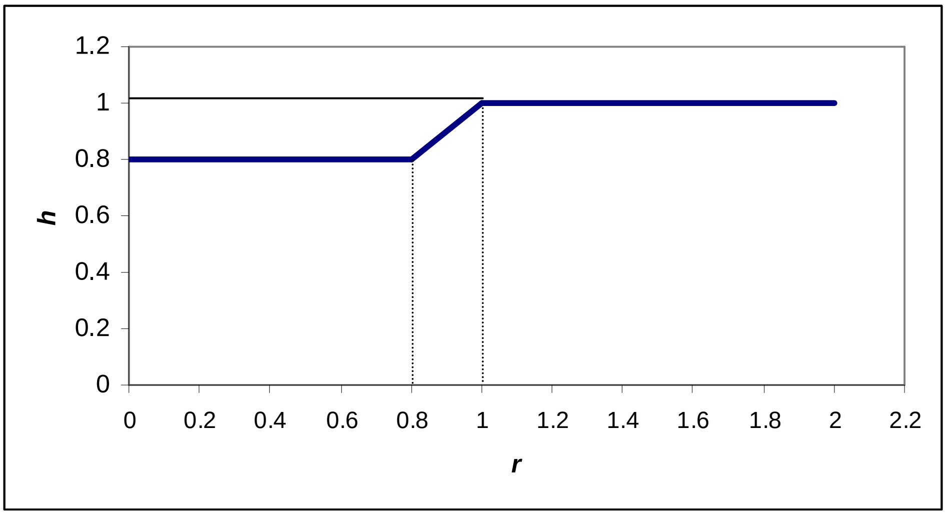
and σ_S^A is the standard error of the regression estimate of s_y^A subject to a lower bound of 0.15; and

δ is a control parameter value which will be re-tuned to achieve the median recovery target of $B_{2025}^{sp}/B_{2006}^{sp}$ of 1.20 specified, for the RC.

Further:

$$\begin{aligned} h(r) &= 0.8 && \text{for} \quad r \le 0.8 \\ &= r && \text{for} \quad 0.8 \le r \le 1.0 \\ &= 1.0 && \text{for} \quad r \ge 1.0 \end{aligned} \qquad (26)$$

i.e.:



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

$$\overline{CPUE}_{init} = \frac{1}{3}\sum_{y'=2003}^{2005}\sum_{A=1}^{3}\lambda_A CPUE_{y'}^{A} \qquad (27)$$

$$\overline{CPUE}_{y} = \frac{1}{3}\sum_{y'=y-3}^{y-1}\sum_{A=1}^{3}\lambda_A CPUE_{y'}^{A} \qquad (28)$$

$$r_y = \frac{\overline{CPUE}_{y}}{\overline{CPUE}_{init}} \qquad (29)$$

and

$$\lambda_1 = 0.003$$
$$\lambda_2 = 0.128$$
$$\lambda_3 = 0.868\ .$$

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 2011 from the RC model:

	q	B^{exp} (MT)
Area A1E	0.0121143	45
Area A1W	0.0035702	505
Area 2+3	0.0010051	959

The relative biomass weights are thus: Area A1E = 45/1508 = 0.03

Area A1W = 504/1508 = 0.33

Area 2+3 = 959/1508 = 0.64

In terms of CPUE what is therefore required is:

$$\begin{aligned} & 0.03\,B^1 + 0.33B^2 + 0.64\,B^3 \\ & = 0.03\frac{CPUE^1}{q_1} + 0.33\frac{CPUE^2}{q_2} + 0.64\frac{CPUE^3}{q_3} \\ & = 2.46CPUE^1 + 93.61CPUE^2 + 632.73CPUE^3 \end{aligned} \qquad (30)$$

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

$$0.003\,CPUE^1 + 0.128\,CPUE^2 + 0.868\,CPUE^3$$

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.:

$$\text{if } TAC_{y+1} > 1.05\,TAC_y \qquad TAC_{y+1} = 1.05\,TAC_y \tag{31}$$

$$\text{if } TAC_{y+1} < 0.95\,TAC_y \qquad TAC_{y+1} = 0.95TAC_y$$

Results of updated assessments

Reference Case OM (RC1)

- CPUE and CAL data receive equal weighting.
- 1999 and 2006 CAL data removed from likelihood.

Table 1 reports these results

Sensitivity OMs

- CAL data are down-weighted by factors of 0.75, 0.5 and 0.1 (Sen1, Sen2 and Sen3)
- Exclude A1E pre-1990 CPUE (RC2)

Table 1 results show that for CAL data down-weighted by 0.5 or less, a very poor fit to the A1E sub-area occurs – with unrealistically large biomasses estimated for A1E. A suggestion put forward at the December 2012 workshop was to exclude pre-1990 A1E CPUE data from the likelihood as these data are highly variable (and possibly therefore unreliable).

The RC OM was thus run excluding the pre-1990 CPUE for A1E from the likelihood (RC2), and the three sensitivity OMs which down-weight the CAL data were also rerun with this data exclusion. It was found however, that excluding the pre-1990 A1E CPUE even for the RC resulted in unreliable results where A1E was predicted to be really large – and the λ^{A1E} value was consequently extremely high (see first column in Table 2).

RC2* was thus run where the recruitment split proportions, λ^{A}, were fixed at values similar to those estimated in previous models:

$$\lambda^{A1E} = 0.15$$

$$\lambda^{A1W} = 0.25$$

$$\lambda^{A2+3} = 0.60$$

Three sensitivities were run where the CAL data are down-weighted by 0.75, 0.50 and 0.1 (Sen1*, Sen2* and Sen3* - see Table 2).

Discussion

The main question we are trying to answer is whether down-weighting the CAL data still produces very different results from a model which gives them equal weight as the CPUE data. In order to compare results with different CAL weightings, the λ values were required to be fixed. Table 2 shows that the resource recovery under a future 345 MT total catch is 1.27 for RC2* (CAL gets equal weighting) and 1.29 for Sen3* (CAL data are down-weighted by 0.1). The CC required to produce B_{sp}(2025/2006) = 1.20 varies between 367 MT (RC2*) and 377 MT (Sen3*).

Plots shown in Figures 1-7 show little difference in model fits to data and model estimated trends between RC2*, Sen2* and Sen3*, except for the Sen3* CAL residuals which do show a worse fit to the CAL data with some systematic trends (Figure 7d).

A task group (Bergh, Butterworth, Johnston, Thompson) proposes that RC1 is used as the RC operating model to re-tuned the OMP, and that this OMP is then run using SEN1 to provide results for a sensitivity to down-weighting the CAL data.

Table 1: Estimated model parameters and –*ln*L values for the current RC and four variants. Unrealistic values are shown as shaded cells.

	N5 Doc 03	**RC1** **With 1999 and 2006 CAL data removed from –lnL (CAL data received equal weight to CPUE)**	**Sen1** **With 1999 and 2006 CAL data removed from –lnL (CAL data downweighted by factor of 0.75)**	**Sen2** **With 1999 and 2006 CAL data removed from –lnL (CAL data downweighted by factor of 0.5)**	**Sen3** **With 1999 and 2006 CAL data removed from –lnL (CAL data downweighted by factor of 0.1)**
		Scl.tpl/n5a.rep	Scl.tpl/n5d.rep	Scl.tpl/n5c.rep	Scl.tpl/n5b.rep
# parameters	219	219	219	219	219
-lnL Total	**-425.64**	**-427.49**	**-399.91**	**-268.44**	**-176.27**
-lnl CPUE	**-121.11**	**-113.53**	**-117.88**	**-131.62**	**-156.30**
-lnl CPUE A1E	-18.02	-17.87	-18.77	-17.44	-17.15
-lnl CPUE A1W	-52.45	-50.42	-51.78	-53.55	-58.20
-lnl CPUE A2+3	-50.64	-45.23	-47.33	-60.63	-80.94
-ln SCI CAL	**-355.03**	**-361.31**	**-337.90**	**-292.17**	**-157.60**
-ln SCI CAL A1E	-9.13	-11.46	-8.41	1.45	4.38
-ln SCI CAL A1W	-96.92	-151.21	-148.45	-142.91	-111.91
-ln SCI CAL A2+3	-248.97	-198.65	-181.03	-150.71	-50.07
K	3258	4895	5132	60018	18467
λ^{A1E}	0.172	0.153	0.158	0.975	0.921
λ^{A1W}	0.280	0.256	0.250	0.009	0.027
λ^{A2+3}	0.548	0.592	0.592	0.016	0.052
B_{sp}(2011) (B_{sp}(2011)/K_{sp})	1160 (0.36)	1650 (0.34)	1777 (0.35)	43278 (0.72)	12579 (0.68)
B_{exp}(2011) (B_{exp}(2011)/K_{exp}) A1E	50 (0.17)	45 (0.16)	60 (0.20)	66970 (0.73)	18492 (0.73)
B_{exp}(2011) (B_{exp}(2011)/K_{exp}) A1W	424 (0.53)	504 (0.58)	484 (0.57)	397 (0.50)	210 (0.33)
B_{exp}(2011) (B_{exp}(2011)/K_{exp}) A2+3	699 (0.33)	959 (0.35)	1053 (0.36)	639 (0.33)	577 (0.33)
B_{sp}(2025/2006) under CC 345 MT	-	1.267	1.257	-	-
CC *s.t.* B_{sp}(2025/2006) = 1.20	-	367 MT	367 MT	-	-

Table 2: Estimated model parameters and –*ln*L values for models where the pre-1990 A1E CPUE is excluded from the likelihood. Unrealistic values are shown as shaded cells.

	RC2 **With 1999 and 2006 CAL data and A1E pre-1990 CPUE data removed from –lnL** **(CAL data received equal weight to CPUE)**	**RC2*** **RC2 but fix the recruitment λ values for each area (0.15, 0.25 and 0.60)**	**Sen1*** **RC2* but CAL data downweighted by factor of 0.75**	**Sen2*** **RC2* but CAL data downweighted by factor of 0.50**	**Sen3*** **RC2* but CAL data downweighted by factor of 0.10**
	Sclnc.tpl/nc1.rep	Xsclnc.tpl/nnv.rep	Nnv2.rep	Nnv3.rep	Nnv4.rep
# parameters	219	216	216	216	216
-lnL Total	**-437.40**	**-429.50**	**-342.53**	**-262.51**	**-171.36**
-lnl CPUE	**-125.96**	**-120.38**	**-124.08**	**-131.05**	**-160.70**
-lnl CPUE A1E	-22.92	-23.33	-23.64	-23.69	-23.34
-lnl CPUE A1W	-50.62	-50.47	-51.61	-53.27	-56.83
-lnl CPUE A2+3	-52.41	-46.57	-48.82	-54.09	-80.53
-ln SCI CAL	**-353.42**	**-358.01**	**-336.29**	**-299.63**	**-147.92**
-ln SCI CAL A1E	-2.49	-9.14	-7.76	-5.81	0.30
-ln SCI CAL A1W	-151.23	-151.33	-148.65	-143.64	-113.65
-ln SCI CAL A2+3	-199.71	-197.54	-179.88	-150.17	-34.58
K	596753	5098	5309	5645	6462
λ^{A1E}	**0.997**	0.15 fixed	0.15 fixed	0.15 fixed	0.15 fixed
λ^{A1W}	0.001	0.25 fixed	0.25 fixed	0.25 fixed	0.25 fixed
λ^{A2+3}	0.002	0.60 fixed	0.60 fixed	0.60 fixed	0.60 fixed
$B_{sp}(2011)$ ($B_{sp}(2011)/K_{sp}$)	464061 (0.78)	1763 (0.35)	1890 (0.36)	2082 (0.37)	2438 (0.38)
$B_{exp}(2011)$ ($B_{exp}(2011)/K_{exp}$) A1E	733506 (0.76)	127 (0.30)	130 (0.31)	130 (0.32)	124 (0.32)
$B_{exp}(2011)$ ($B_{exp}(2011)/K_{exp}$) A1W	477 (0.57)	511 (0.60)	507 (0.59)	489 (0.57)	360 (0.44)
$B_{exp}(2011)$ ($B_{exp}(2011)/K_{exp}$) A2+3	676 (0.34)	997 (0.36)	1091 (0.37)	1234 (0.39)	1386 (0.42)
$B_{sp}(2025/2006)$ under CC 345 MT	-	1.294	1.277	1.252	1.128
CC *s.t.* $B_{sp}(2025/2006)$ = 1.20	-	377	375	368	350

Figure 1: **Fits to CPUE** for RC1 (excludes 1999 and 2006 CAL data), RC2* (excludes 1999 and 2006 CAL data, excludes pre-1990 A1E CPUE data and fixes the λ values), SEN2* (RC2* but downweights CAL data by 0.5) and Sen3*(RC2* but downweights CAL data by 0.10).

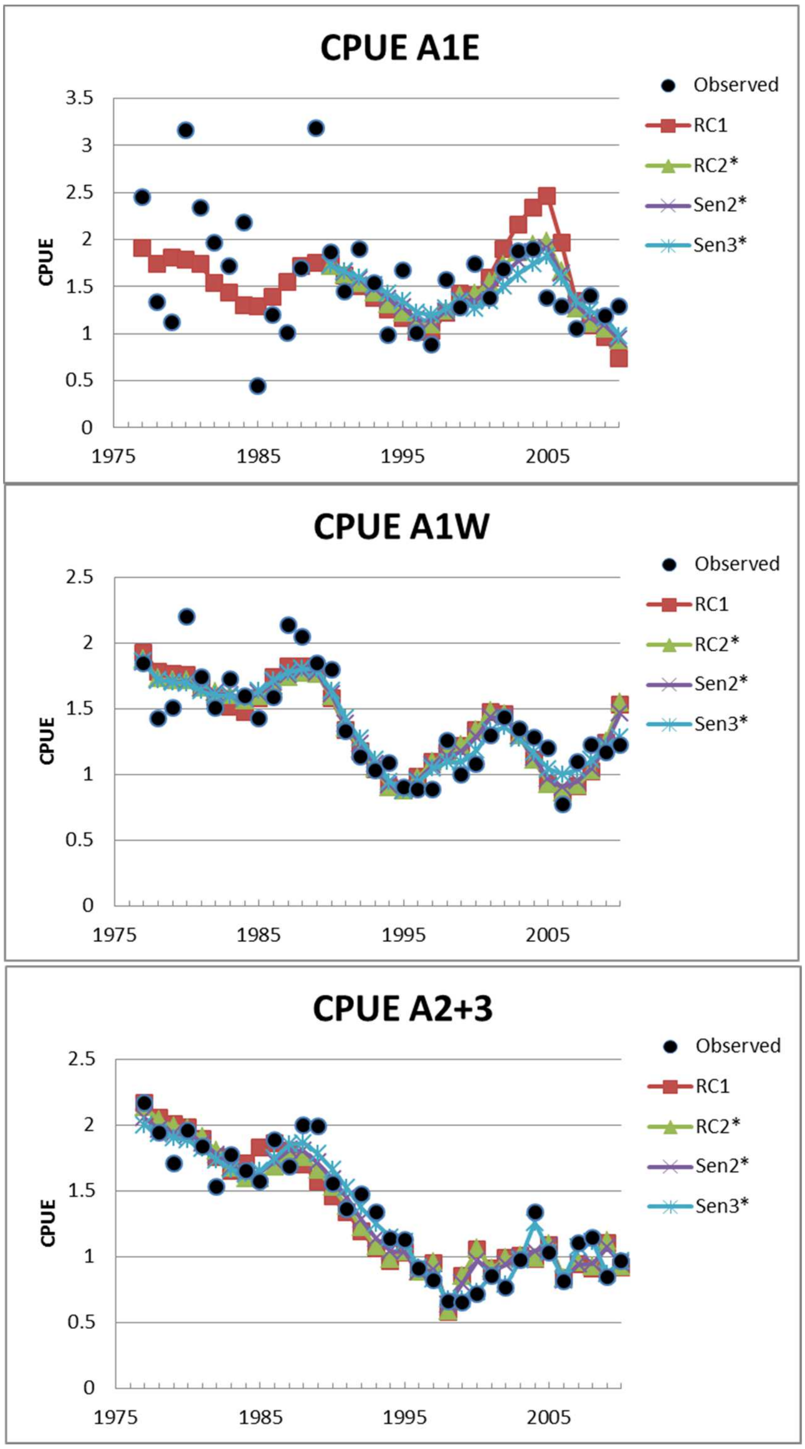


Figure 2: Model estimates of **exploitable biomass relative to *K*** for RC1 (excludes 1999 and 2006 CAL data), RC2* (excludes 1999 and 2006 CAL data, excludes pre-1990 A1E CPUE data and fixes the λ values), SEN2* (RC2* but downweights CAL data by 0.5) and Sen3*(RC2* but downweights CAL data by 0.10).

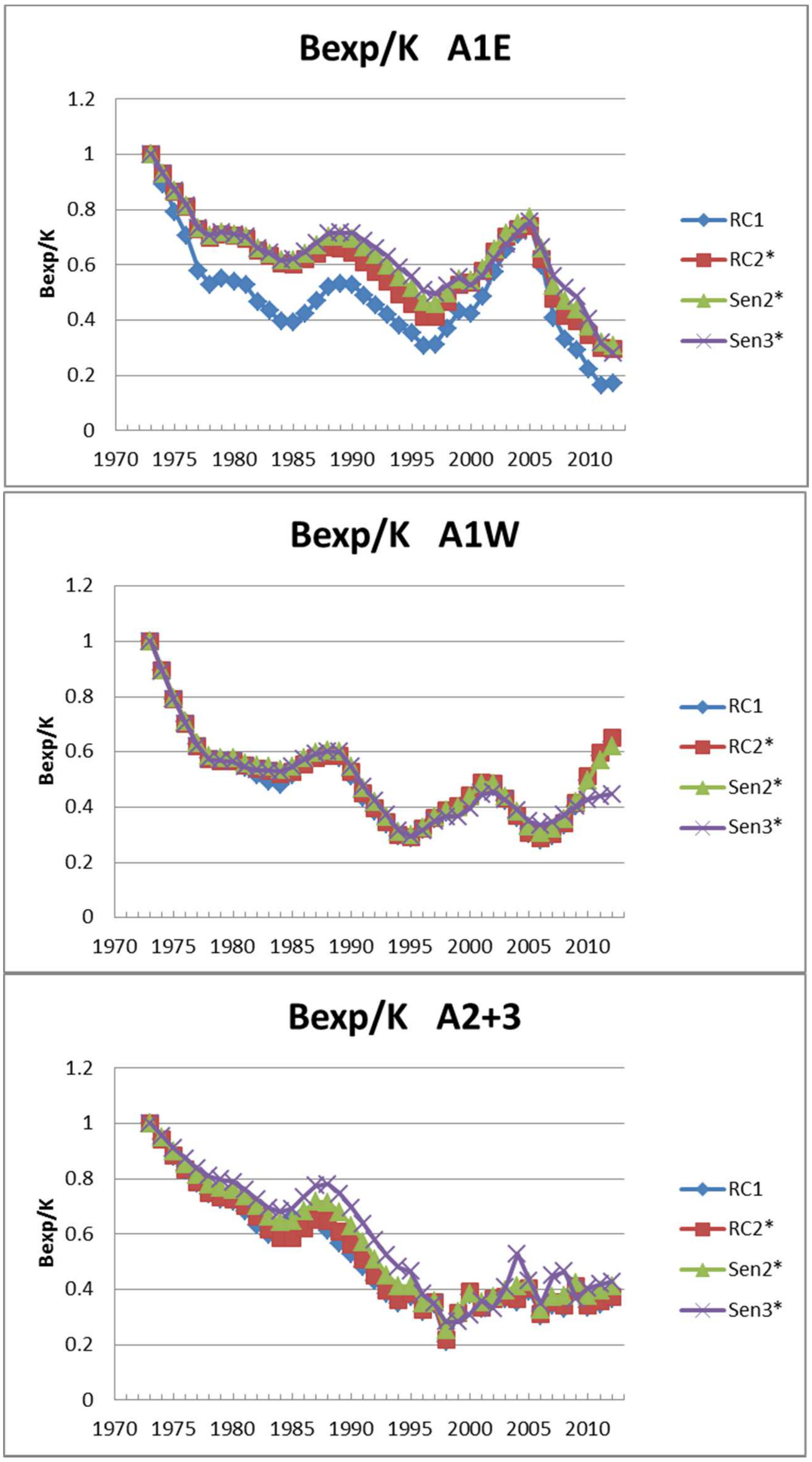


Figure 3: Model estimates of **spawning biomass relative to *K*** for RC1 (excludes 1999 and 2006 CAL data), RC2* (excludes 1999 and 2006 CAL data, excludes pre-1990 A1E CPUE data and fixes the λ values), SEN2* (RC2* but downweights CAL data by 0.5) and Sen3*(RC2* but downweights CAL data by 0.10).

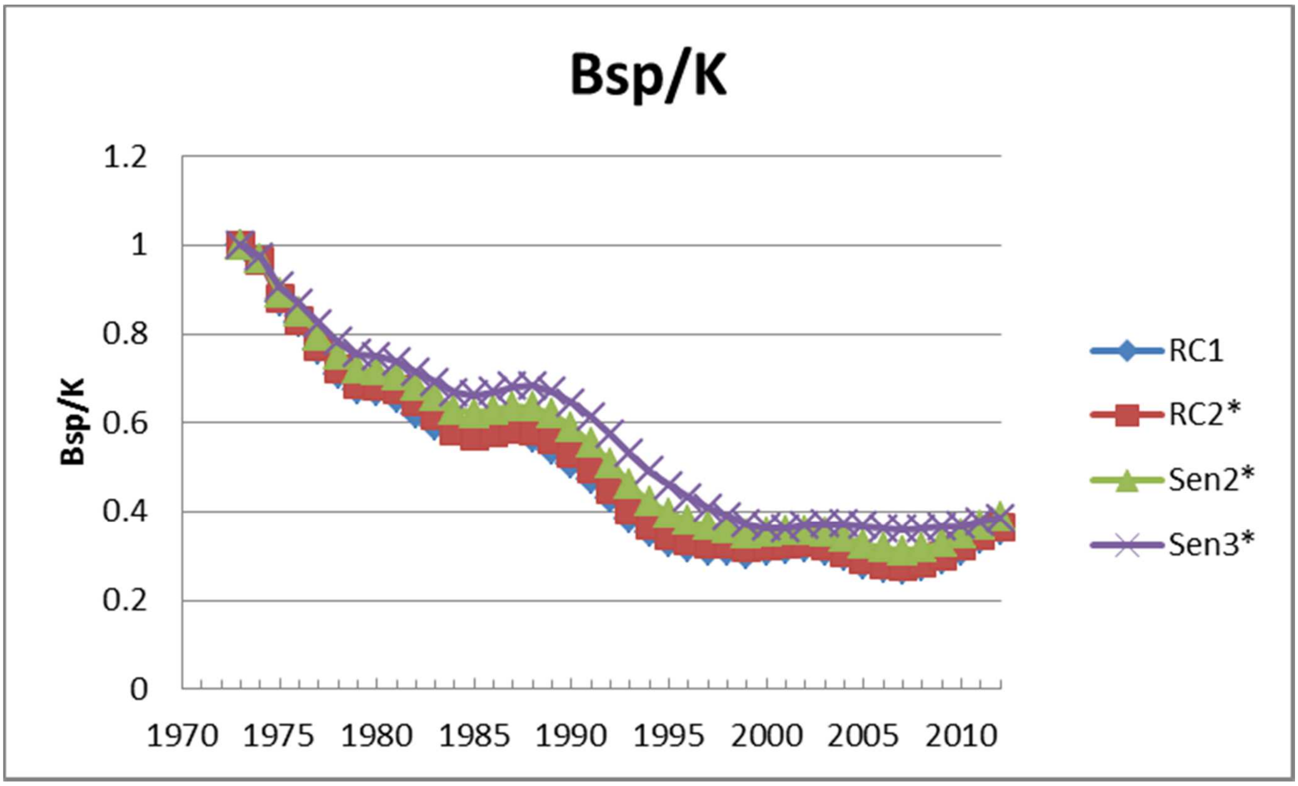


Figure 4: Model estimates of ***F*** for RC1 (excludes 1999 and 2006 CAL data), RC2* (excludes 1999 and 2006 CAL data, excludes pre-1990 A1E CPUE data and fixes the λ values), SEN2* (RC2* but downweights CAL data by 0.5) and Sen3*(RC2* but downweights CAL data by 0.10).

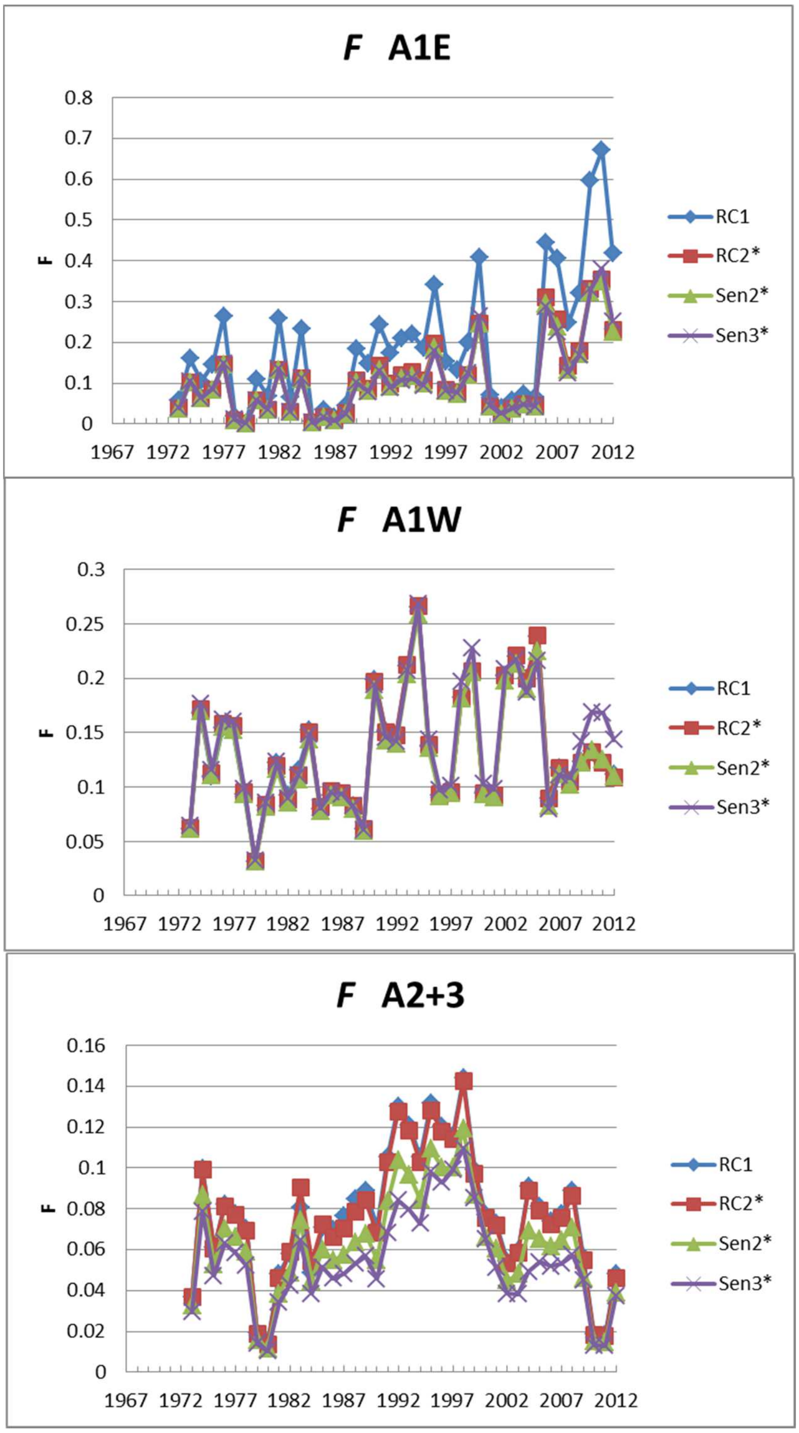


Figure 5: Model estimates of **stock-recruitment residuals** for RC1 (excludes 1999 and 2006 CAL data), RC2* (excludes 1999 and 2006 CAL data, excludes pre-1990 A1E CPUE data and fixes the λ values), SEN2* (RC2* but downweights CAL data by 0.5) and Sen3*(RC2* but downweights CAL data by 0.10).

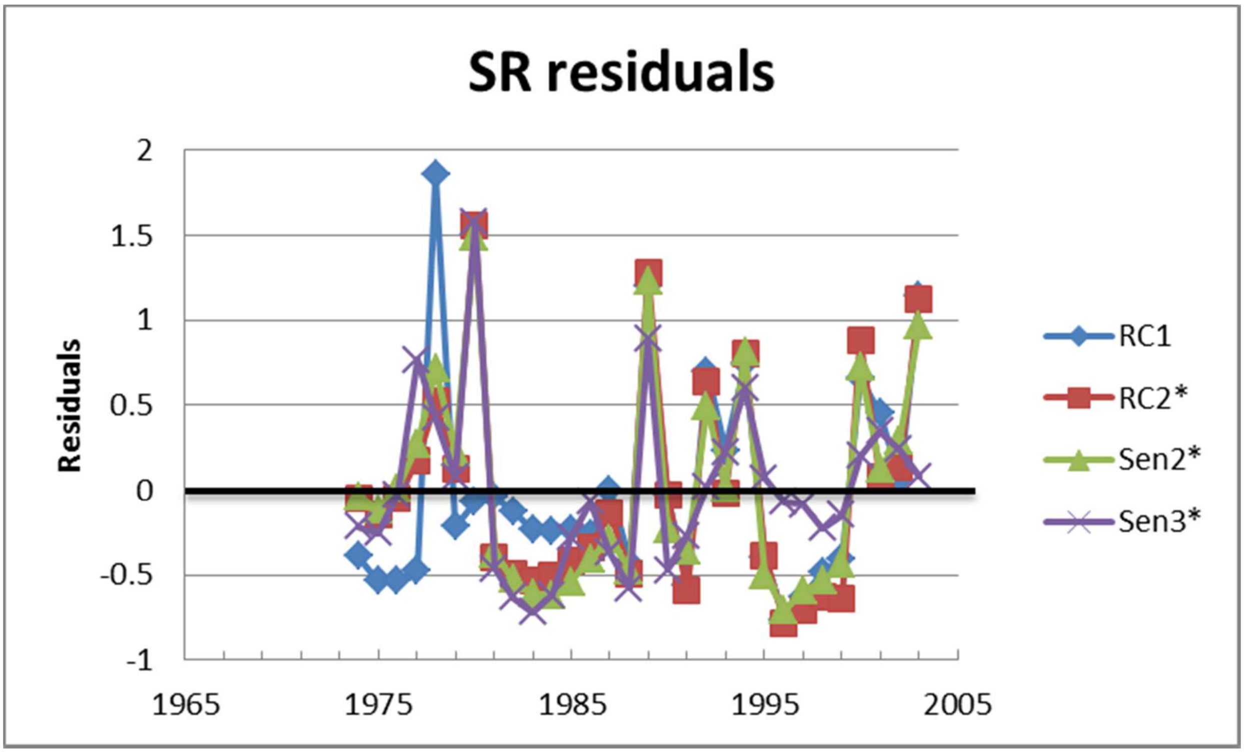


Figure 6a: RC1 estimated selectivity functions for A1E, A1W and A2+3. Note that the A2+3 selectivity functions vary over time for the period 1995-2010 and these are shown in Figure 6b.

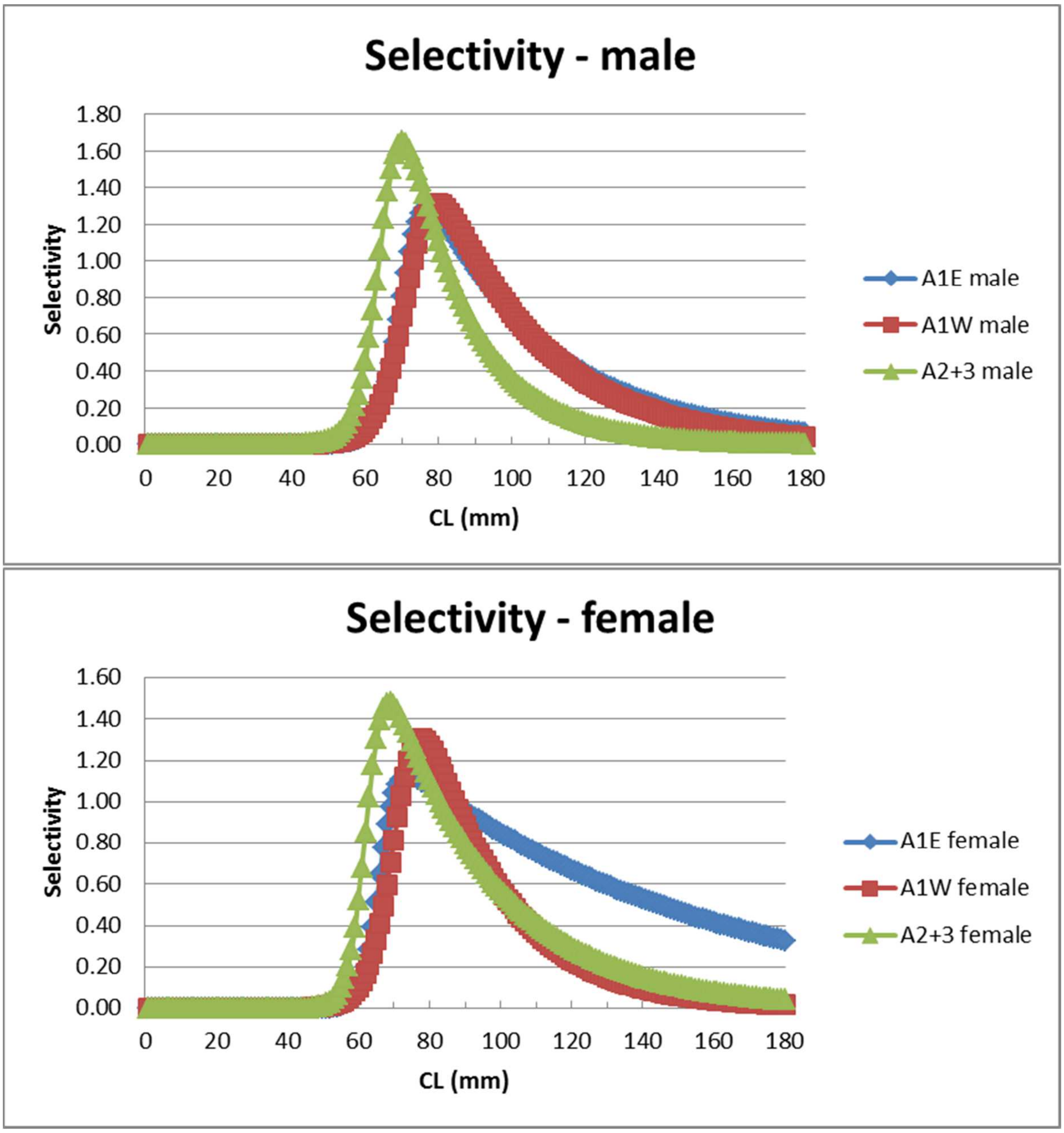


Figure 6b: RC1 estimated selectivity function for A2+3 for 1995-2010.

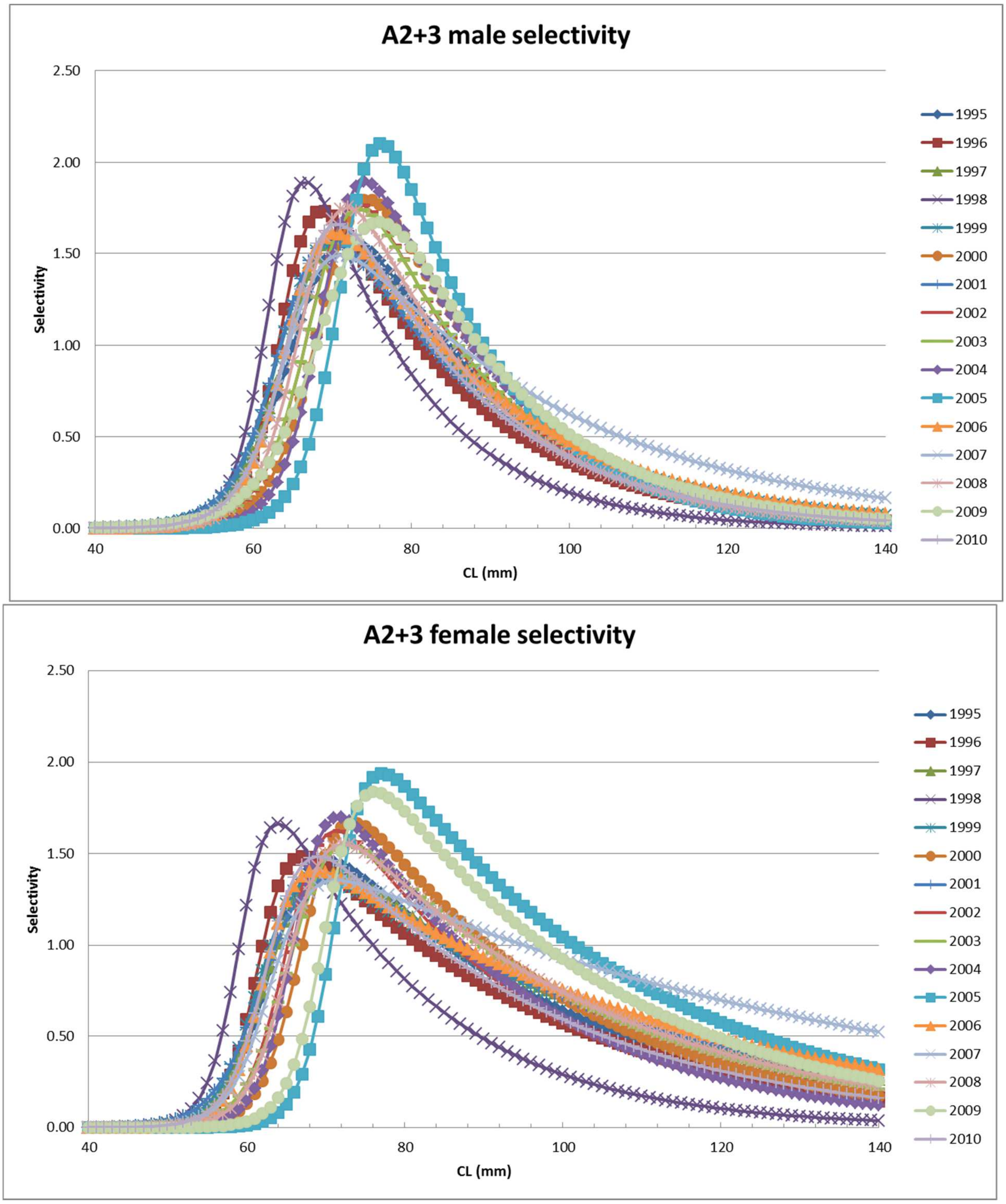


Figure 7a: RC1 catch-at-length residuals.

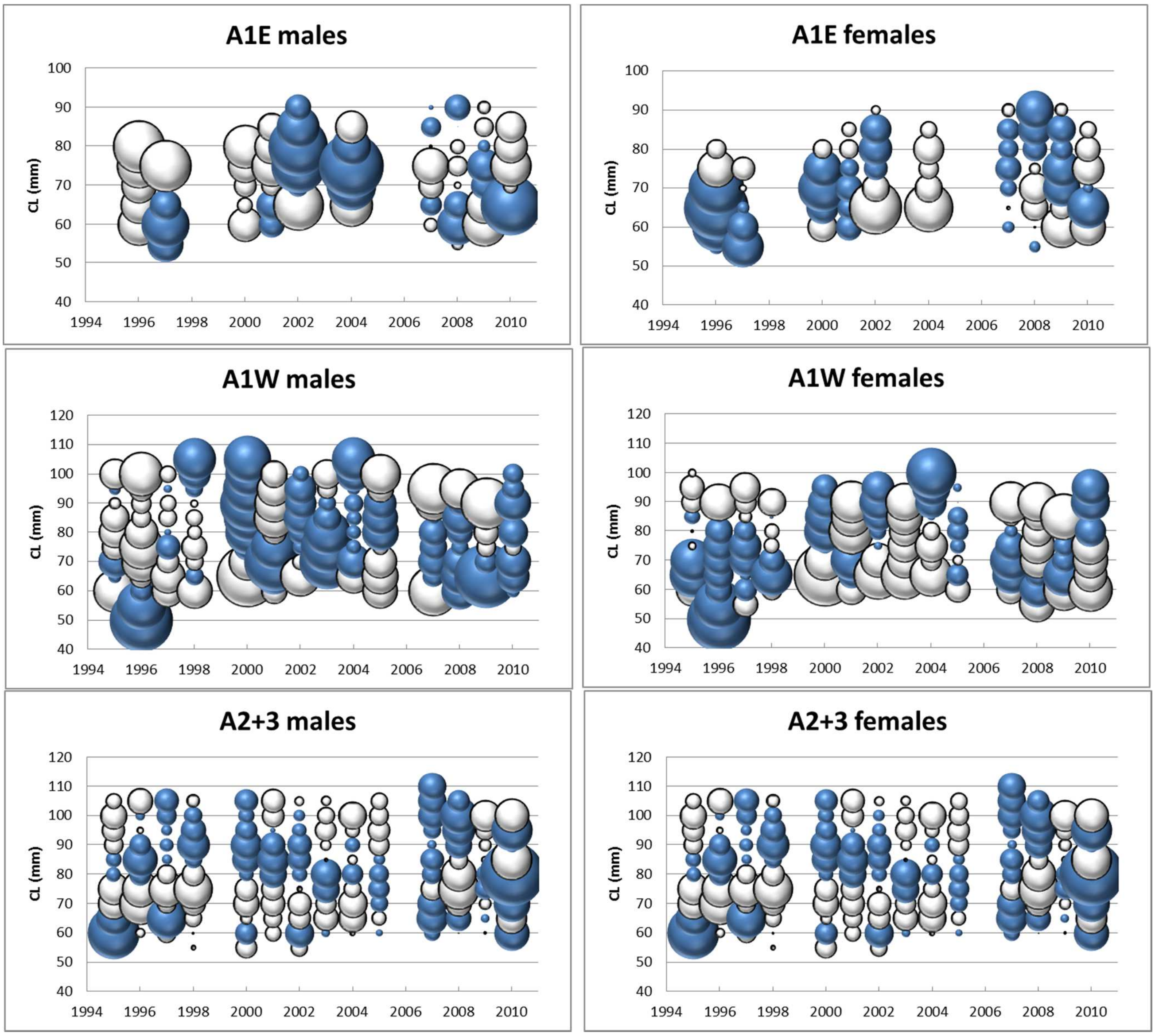


Figure 7b: RC2* catch-at-length residuals.

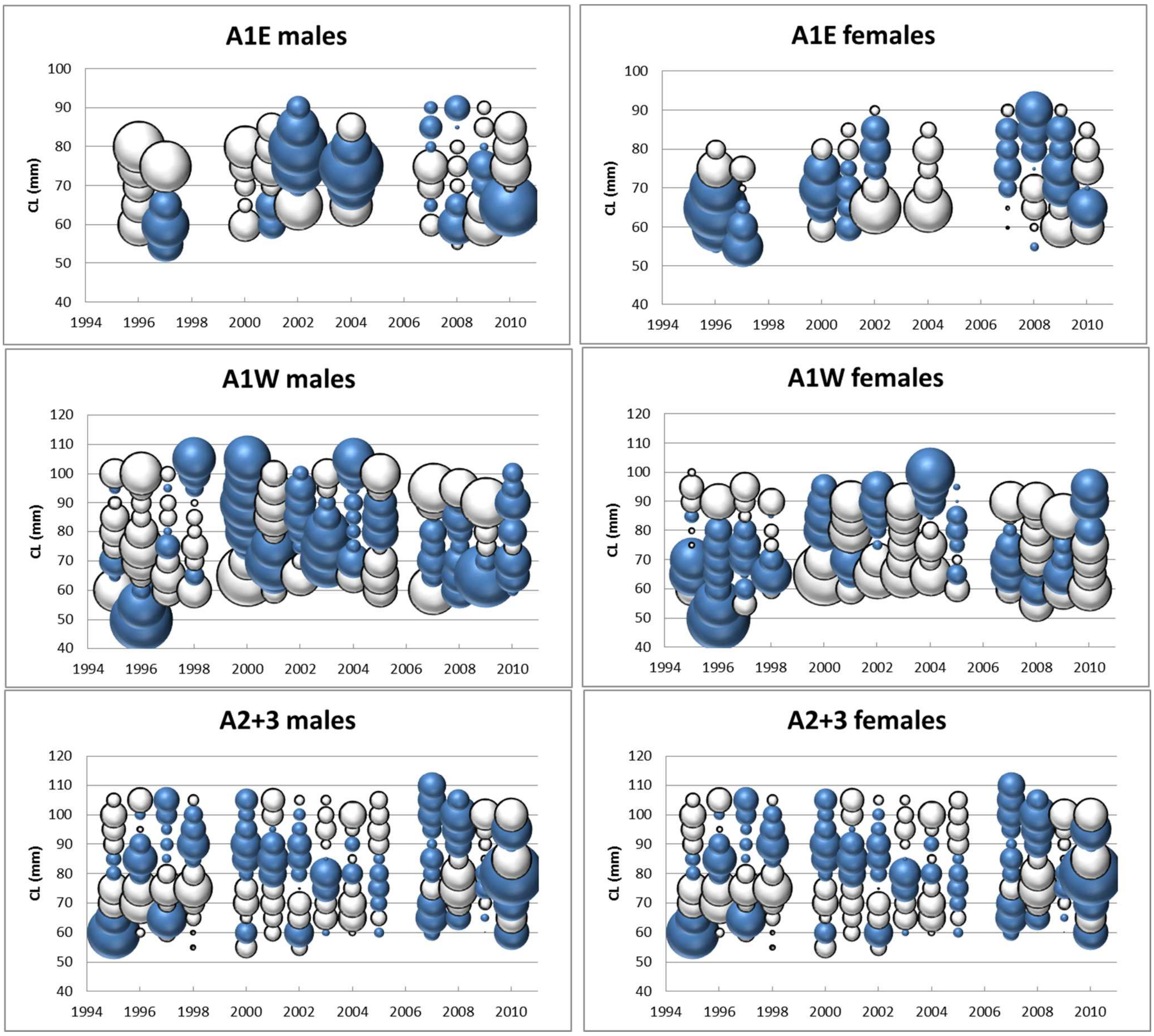


Figure 7c: Sen2* catch-at-length residuals.

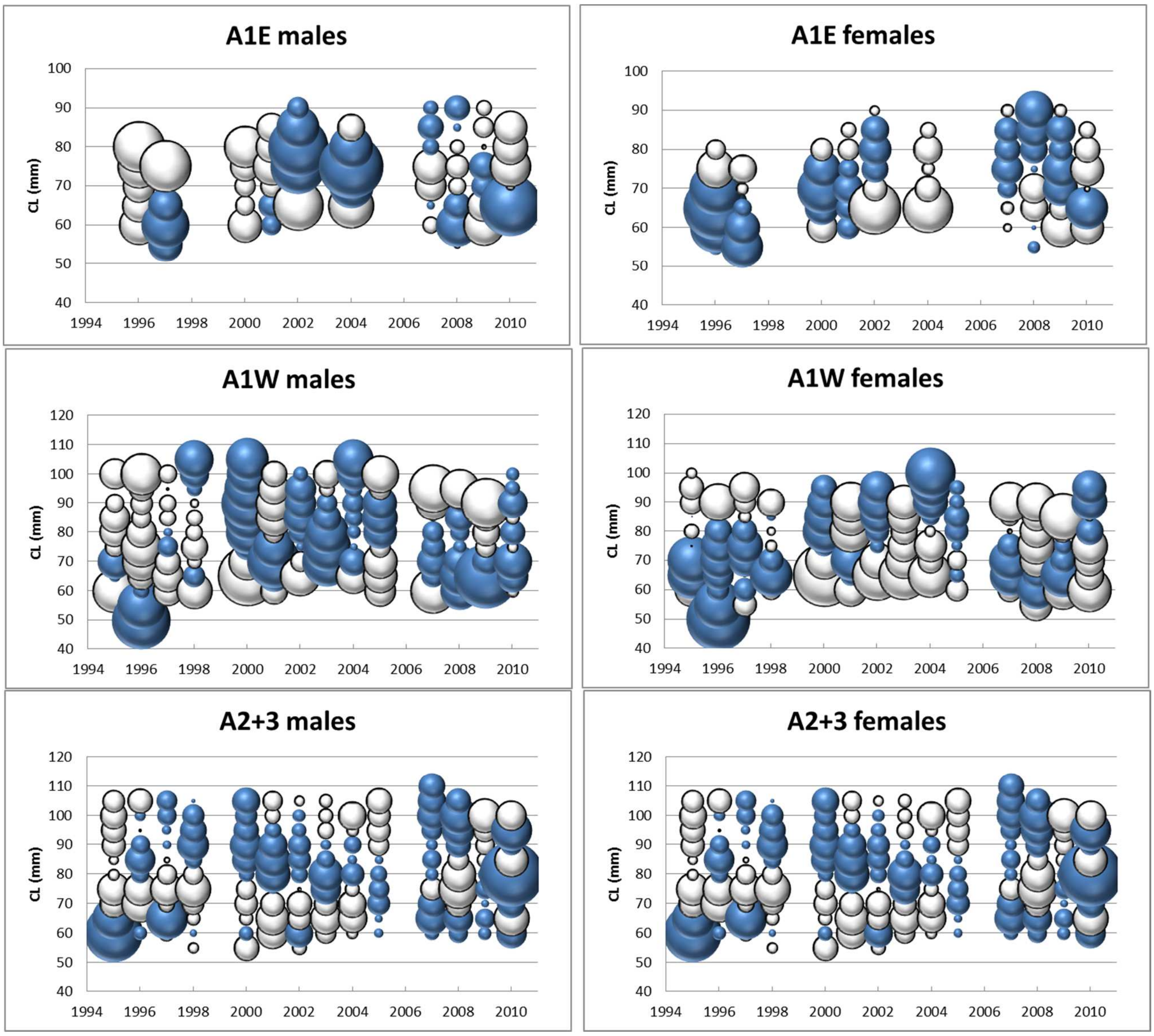


Figure 7d: Sen3* catch-at-length residuals.