The new West Coast rock lobster OMP based on an area-disaggregated approach

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Summary

The OMP currently being developed for the West Coast Rock Lobster is different from the three previous OMPs applied to manage the resource (see Johnston and Butterworth 2005), in that this new OMP will provide TACs for each of the five super-areas on an annual basis. During 2006, considerable work was focussed on the development of assessment models for each super-area. These assessment models now form the "operating models" which are used for testing alternate OMP candidates and are described in ANSW/JUL07/WCRL/ASS/1 and 2.

The new OMP uses data (trap and hoop CPUE, FIMS, somatic growth rate) from each area (where available), combines these data into a single index (for each data type), produces a global TAC, and then uses a series of rules to split this global TAC into TACs at the super-area level. At the same time, estimates of recreational catch for each super-area are taken into account, as well as ensuring that super-area TACs will allow the allocations to the limited rights holders (smaller scale operators restricted to a particular super-area) to be taken each year.

Contents

[1] Note that season 2006 refers to the 2006/07 season

1. Future Scenarios and stochastic simulation

A number of scenarios regarding the future recruitment and somatic growth were identified and are listed below. There are also three underlying models of resource dynamics/abundance – the reference case model, and then two models which allow for either a larger or smaller current population size. Following recommendations made at the DEC05 international rock lobster workshop, each of the scenarios was assigned a weight. The combination of the uncertainties listed below produce a total of 27 scenarios. Each OMP candidate is run for all 27 scenarios, with the results of each scenario being weighted by a value reflective of that scenario's total weight.

Stochastic Simulations

Instead of running all 27 scenarios 50 times each (as with previous OMP developments), only 300 simulations are run in total, selecting amongst the scenarios in proportion to their relative weights. For each simulation *S*, generate *x* from U[0,1]. Using the value of *x* and cumulative weights in Table 1, the respective "scenario" will be selected for each simulation. Using a total of 300 simulations will ensure a reasonable chance that each scenario is drawn at least once. The 90% probability intervals would normally be estimated by the 15th and 286th ordered values in the set of 300, but to allow for possible discontinuities given the small number of simulations, these are replaced by estimated from linear regressions through the 13th to 17th and 284th to 288th ordered values.

Scenarios

Median Future recruitment	**WT**
• FRM: Geometric Mean of $R_{75}, R_{80}, R_{85}, R_{90}$ and R_{95}	0.60
• FRH: Maximum of $R_{75}, R_{80}, R_{85}, R_{90}$ and R_{95}	0.30
• FRL: Minimum of $R_{75}, R_{80}, R_{85}, R_{90}$ and R_{95}	0.10

Future Somatic growth (2005+)	**WT**
• FSGL: = FSGM for 3 years (2005, 2006, 2007) then will equal the 1989-2004 average (see Figure 1)	0.50
• FSGM: $\uparrow$ linearly to 1968-2004 ave over 10 yrs	0.40
• FSGH: $\uparrow$ linearly to 1968-2004 ave over 3 yrs	0.10

[The above apply to the growth rates for Areas 3-4, 5-6, 7 and 8. The somatic growth rate for Area 1-2 is assumed to remain constant in the future at the 1989-2004 average level for all scenarios.]

Current (2005) Abundance (B75)	**WT**
• RC: Best Estimate (from current RC1-like model)	0.50
• ALTL: Estimated lower 12.5%ile[2]	0.25
• ALTH: Estimated upper 12.5%ile	0.25

[2] See RLWS/DEC05/ASS/7/1/1 equations 1-5 for details

Table 1: The combinations of these uncertainties results in 27 possible scenarios.

Scenario	Recruitment	Somatic growth	Current Abundance	R WT	G WT	A WT	Total WT	Cum WT
1	FRM	FSGL	RC	0.6	0.5	0.5	0.15	0.15
2	FRM	FSGL	ALTL	0.6	0.5	0.25	0.075	0.225
3	FRM	FSGL	ALTH	0.6	0.5	0.25	0.075	0.3
4	FRM	FSGM	RC	0.6	0.4	0.5	0.12	0.42
5	FRM	FSGM	ALTL	0.6	0.4	0.25	0.06	0.48
6	FRM	FSGM	ALTH	0.6	0.4	0.25	0.06	0.54
7	FRM	FSGH	RC	0.6	0.1	0.5	0.03	0.57
8	FRM	FSGH	ALTL	0.6	0.1	0.25	0.015	0.585
9	FRM	FSGH	ALTH	0.6	0.1	0.25	0.015	0.6
10	FRH	FSGL	RC	0.3	0.5	0.5	0.075	0.675
11	FRH	FSGL	ALTL	0.3	0.5	0.25	0.0375	0.7125
12	FRH	FSGL	ALTH	0.3	0.5	0.25	0.0375	0.75
13	FRH	FSGM	RC	0.3	0.4	0.5	0.06	0.81
14	FRH	FSGM	ALTL	0.3	0.4	0.25	0.03	0.84
15	FRH	FSGM	ALTH	0.3	0.4	0.25	0.03	0.87
16	FRH	FSGH	RC	0.3	0.1	0.5	0.015	0.885
17	FRH	FSGH	ALTL	0.3	0.1	0.25	0.0075	0.8925
18	FRH	FSGH	ALTH	0.3	0.1	0.25	0.0075	0.9
19	FRL	FSGL	RC	0.1	0.5	0.5	0.025	0.925
20	FRL	FSGL	ALTL	0.1	0.5	0.25	0.0125	0.9375
21	FRL	FSGL	ALTH	0.1	0.5	0.25	0.0125	0.95
22	FRL	FSGM	RC	0.1	0.4	0.5	0.02	0.97
23	FRL	FSGM	ALTL	0.1	0.4	0.25	0.01	0.98
24	FRL	FSGM	ALTH	0.1	0.4	0.25	0.01	0.99
25	FRL	FSGH	RC	0.1	0.1	0.5	0.005	0.995
26	FRL	FSGH	ALTL	0.1	0.1	0.25	0.0025	0.9975
27	FRL	FSGH	ALTH	0.1	0.1	0.25	0.0025	1

2. Other Assumptions for the Future

Future trap:hoop ratios
The previous OMP testing process assumed a trap:hoop catch ratio of 0.70:0.30 for all years in the future. Now different ratios are assumed for each super-area (these are based on actual recent trap and hoopnet catches). These trap:hoop ratios are:

Area 1-2 = 0:100
Area 3-4 = 10:90
Area 5-6 = 0:100
Area 7 = 100:0
Area 8 = 78:22

It is assumed that these ratios continue unchanged into the future.

Future Poaching level
The previous OMP testing process assumed future annual poaching levels to remain constant at 500 MT (for the entire resource). Currently the following levels of future poaching are assumed for each super-area:

Area 1-2 = 5 MT
Area 3-4 = 12.5 MT
Area 5-6 = 12.5 MT
Area 7 = 70 MT
Area 8 = 400 MT

It is assumed that these levels continue unchanged into the future.

Future Recreational take
The OMP will need to allocate a certain amount "globally", i.e. for all areas combined, for the recreational take each year.

The following algorithm is to be applied:

$C_t^{rec} = 320$ MT initially

If $C_t^{rec} / TAC_t^G > 0.12 TAC_t^G$ then $C_t^{rec} = 0.10 TAC_t^G$
If $C_t^{rec} / TAC_t^G < 0.08 TAC_t^G$ then $C_t^{rec} = 0.10 TAC_t^G$

If $C_t^{rec} > 450$ MT then $C_t^{rec} = 450$ MT

where C_t^{rec} is the overall recreational take for year *t*, and TAC_t^G is the "total" or "global" (commercial plus recreational) TAC for year *t* as output by the OMP.

The following % breakdown of the overall recreational take (C_t^{rec}) by super-area is assumed; these %'s remain unchanged over time:

Area 1-2 = 2%
Area 3-4 = 12.5%
Area 5-6 = 12.5%
Area 7 = 4%
Area 8 = 69%

Future recruitment (for FRM scenario)
For each super-area:

Future R_y: where y = 2005, 2010, 2015, 2020, 2025 and 2030; linearity between each of these years (and between 2000 and 2005).

Deterministic: $R_y = \bar{R}e^{-\frac{1}{2}\sigma^2}$

Stochastic: R_y randomly selected from $\bar{R}e^{\varepsilon_y}$, where,

$$\ln \bar{R} = \frac{1}{5}\left(\ln R_{75} ... \ln R_{95}\right)$$

$$\sigma = \text{SD of } \left(\ln R_{75}, ... \ln R_{95}\right)$$

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

For FRH and FRL, the $\bar{R}$ is replaced by either the maximum or minimum R amongst $R_{75}, R_{80}, R_{85}, R_{90}$ and R_{95}. Note that for A1-2, the minimum R is selected from the R_{80}, R_{85}, R_{90} and R_{95} range only, as it was found in the model fitting process that the R_{75} was unrealistically small.

3. Future Data

Future data available each year
This refers to data which it can reliably (i.e. almost certainly) be assumed will be available, based on recent years. The following is assumed:

Area	Trap CPUE	Hoop CPUE	FIMS	Somatic growth
1-2	No	Yes	No	Yes
3-4	No	Yes	Yes	Yes
5-6	No	Yes	Yes	Yes
7	Yes	No	Yes	Yes
8	Yes	Yes	Yes	Yes

Future data apply to seasons from 2005 onwards (except for somatic growth where the 2005 data have recently been supplied), and future TAC levels apply to seasons from 2007 onwards.

Data that are input to the OMP (for the super-areas for which they are available) are generated as follows:

a) Future commercial Trap CPUE estimates

Deterministic: $$C\hat{P}UE_y^{trap} = q^{trap} \sum_{l \geq l_{min}}^{180} \left[w_l^m b_l^{m,trap}(y) N_l^m(y) + w_l^f b_l^{f,trap}(y) N_y^f(y) \right]$$

Stochastic: For simulation S, $\hat{CPUE}_y^{trap,S} = \hat{CPUE}_y^{trap} e^{\varepsilon_y^S}$,

where $\varepsilon_y^S \sim N(0,\sigma^2)$, and where σ is taken from the model fit to the trap CPUE data for that super-area and is as follows:

A1-2: N/A
A3-4: N/A
A5-6: N/A
A7: σ =0.293
A8: σ =0.150

b) Future commercial Hoop CPUE estimates

Deterministic: $\hat{CPUE}_y^{hoop} = q^{hoop} \sum_{l \geq l_{min}}^{180} \left[w_l^m b_l^{m,hoop}(y) N_l^m(y) + w_l^f b_l^{f,hoop}(y) N_y^f(y) \right]$

Stochastic: For simulation S, $\hat{CPUE}_y^{hoop,S} = \hat{CPUE}_y^{hoop} e^{\varepsilon_y^S}$,

where $\varepsilon_y^S \sim N(0,\sigma^2)$, and where σ is taken from the model fit to the hoopnet CPUE for that super-area and is as follows:

A1-2: σ =0.296
A3-4: σ =0.479
A5-6: σ =0.118
A7: σ =N/A
A8: σ =0.150

c) Future FIMS estimates

Deterministic: $\hat{FIMS}_y = q^{FIMS} \sum_{l \geq 40}^{180} \left[b_l^{m,FIMS}(y) N_l^m(y) + b_l^{f,FIMS}(y) N_y^f(y) \right]$

Stochastic: For simulation S, $\hat{FIMS}_y^S = \hat{FIMS}_y e^{\varepsilon_y^S}$,where

$\varepsilon_y^S \sim N(0,\sigma^2)$, and where σ is taken from the model fit to the FIMS CPUE data for that super-area which is as follows:

A1-2: N/A
A3-4: σ =1.594
A5-6: σ =1.072
A7: σ =0.785
A8: σ =0.150

d) Future somatic growth

The β_y^m value (being the annual growth of a 70mm male rock lobster) is used as the index of somatic growth rate for each super-area.

Stochastic: $\beta_y^{m,S} = \beta_y^m + \varepsilon_y^S$, where

$\varepsilon_y^S \sim N(0,\sigma^2)$, and the σ values for each super-area (as calculated from the 1990-2004 observed values) are as follows:

A1-2: σ =0.79
A3-4: σ =0.51
A5-6: σ =0.51
A7: σ =1.18
A8: σ =0.51

Note that due to the fact that future somatic growth data from A5-6 are unlikely to eventuate, and that the moult probability model treats the A3-4, A5-6 and A8 somatic growth as the same, then when generating random error (as described above) for the somatic growth rates for these three super-areas, the same error is applied to each of these super-areas (although varying from year to year). This ensures that somatic growth observations will either go up or down in tandem for these three super-areas.

4. How to combine super-area data into single indices for input to the OMP

Combined CPUE and FIMS indices:

The "global" OMP requires a single index for each data source (somatic growth, trap CPUE, hoop CPUE and FIMS) for each year in the future.

STEP 1: For each area for which data are assumed available, there will be for any year (for trap CPUE as example):

$$CPUE_{2006}^{trap,A1-2}, CPUE_{2006}^{trap,A3-4}, CPUE_{2006}^{trap,A5-6}, CPUE_{2006}^{trap,A7}, CPUE_{2006}^{trap,A8}$$

STEP 2: Evaluate the geometric means of the CPUEs (and FIMS) for the super-area concerned over the last five years (i.e. over 2000…2004),

STEP 3: Express the values for CPUE generated in Step 1 as fractions of these means, e.g:

$$CPUE_{2006}^{trap,A1-2} \Rightarrow X_{2006}^{trap,A1-2} = \frac{CPUE_{2006}^{trap,A1-2}}{geomtric\ mean\ 2000...2004\ values}$$

STEP 4: Calculate a combined CPUE index as follows:

$$X_{2006}^{trap,TOTAL} = w_{A1-2}^{trap} X_{2006}^{trap,A1-2} + w_{A3-4}^{trap} X_{2006}^{trap,A3-4} + ... w_{A8}^{trap} X_{2006}^{trap,A8}$$

where $w_{A1-2}^{trap} + w_{A3-4}^{trap} + ... w_{A8}^{trap} = 1$

e.g.: for trap and hoop CPUE get B^{75} for 2000-2004 for each super-area: $\overline{B}_{A1-2}^{75}, \overline{B}_{A3-4}^{75}, \overline{B}_{A5-6}^{75}, \overline{B}_{A7}^{75}, \overline{B}_{A8}^{75}$. Note that these are selectivity-weighted biomasses.

Then $\overline{B}_{TOTAL}^{75} = \sum_{A=1..8} \overline{B}_{A}^{75}$ and

$$w_{A1-2}^{trap} = w_{A1-2}^{hoop} = \frac{\overline{B}_{A1-2}^{75}}{\overline{B}_{TOTAL}^{75}} \text{ etc.}$$

For FIMS, as above, but use B^{60} instead of B^{75} (again, use the selectivity weighted biomass).

Remember there will be a lack of data types for some super-areas, so that summations above are adjusted accordingly:
Traps: A7 and A8 only
Hoops: A1-2, A3-4, A5-6 and A8 only
FIMS: A3-4, A5-6, A7 and A8 only.

Combined somatic growth index:

All that is needed is an index e.g. 70mm male somatic growth as used in each separate assessment.

Use similar weighting factors e.g. $w_{A1-2}^{SG} = \frac{\overline{B}_{A1-2}^{male,70}}{\overline{B}_{TOTAL}^{male,70}}$ as for trap and hoop CPUE (except that now weighting factors for all five super-areas are used). Note also the biomass relates to total male biomass above 70mm only.

Thus $\beta_t = w_{A1-2}^{SG} \beta_t^{A1-2} + w_{A3-4}^{SG} \beta_t^{A3-4} + w_{A5-6}^{SG} \beta_t^{A5-6} + w_{A7}^{SG} \beta_t^{A7} + w_{A8}^{SG} \beta_t^{A8}$
where:
β_t is the combined somatic growth rate of a 70mm male lobster in year *t*.

Since the assessments are now finalised, the biomasses above are all available and hence also the weighting factors which are now fixed. The table below lists these *w* values. [Note that the blanks indicate that data are not expected from that super-area for that gear type in the future, and are hence omitted from the OMP.]

NB: the w_A calculation is based on the best (RC1-like) assessment, and yields the following:

	w_A^{trap}	w_A^{hoop}	w_A^{FIMS}	w_A^{SG}
A1-2	-	0.025	-	0.018
A3-4	-	0.234	0.157	0.176
A5-6	-	0.152	0.075	0.082
A7	0.400	-	0.188	0.229
A8	0.600	0.588	0.580	0.495

Note: the OMP currently presented to this workshop assumes that as the only TAC required for A12 and A56 is that for the limited rights holders (which are fixed amounts), i.e. the OMP itself is not required to calculate any further TAC for these two areas, input data from these two areas are excluded as input into the OMP. Combined super-area data indices thus consider only super-areas A34, A7 and A8.

5. How to split the global (combined) TAC generated from the OMP

The OMP TAC setting rule will produce a global TAC each year - TAC_t^G .

The adjustment to be made is that 320 MT (or a related amount – see rules described above for modifications to the recreational catch) must be removed for the recreational catch.

The remaining (commercial) TAC must then be split into super-area TACs.

STEP 1: For each super-area we have 1-3 abundance index time series. For each time index, linearly regress *ln*(index) *vs* year for the last seven years of data, and calculate the slope.

STEP 2: If there is more than one series for a super-area, take the average of the slopes for each series, using inverse variance weighting as follows:

$$slope = \frac{\left(\frac{slope_{trap}}{\sigma^2_{slope_{trap}}} + \frac{slope_{hoop}}{\sigma^2_{slope_{hoop}}} + \frac{slope_{FIMS}}{\sigma^2_{slope_{FIMS}}}\right)/3}{\frac{1}{\sigma^2_{slope_{trap}}} + \frac{1}{\sigma^2_{slope_{hoop}}} + \frac{1}{\sigma^2_{slope_{FIMS}}}}$$

(assuming three series), where

$$\sigma^2 = \frac{1}{n-2} slope^2 \frac{1-r^2}{r^2}$$

from each regression, where *r* is the correlation coefficient and *n* = 7 given that seven years of data are used.

STEP 3: If these resultant slopes are above 0.15 or below -0.15, replace them with the bound concerned.

STEP 4: Take previous year's allocation for the super-area and multiply it by (1+*slope*), giving a new set of allocations by super-area, which will not necessarily total to the new overall commercial TAC. If they do not, simply scale them all by the same proportion so that they do total to match that.

Step 5: Ensure that the commercial TAC for each super-area is at least as large as the amount proposed for allocation to the limited rights holders. These amounts are set out in the next section.

For a certain area's commercial TAC is less that the limited rights holders allocated amount, then this TAC is increased to equal the limited rights holders allocation for that super-area. The TACs for the remaining areas are then re-scaled using the same ratios as for Step 4. This process continues until the TACs for all super-areas comply with the criteria of being equal or larger than the limited rights holders allocation, and that the sum of the TAC over the super-areas equals the newly calculated commercial TAC.

6. Limited Rights Holders Quotas

The limited rights holders quota values are treated as minimum TACs for each super-area. The table below lists the quotas set aside for the limited rights holders in each super-area (Cockroft pers. commn).

Super-Area	**Limited rights holders TAC**
Area 1-2	30 MT
Area 3-4	90 MT
Area 5-6	40 MT
Area 7	0 MT
Area 8	400 MT

7. TAC values used for 2006/07 season

The OMP trials use the actual 2006/07 season's TAC and its super-area allocation. These values are:

Super-area	Commercial TAC (Limited + Full commercial)
Area 1+2	30 MT
Area 3+4	100 MT
Area 5+6	40.25 MT
Area 7	821.75 MT
Area 8	1565 MT

8. Output performance statistics

The following superscripts are used in the summary statistic notation:

comm refers to commercial catches (offshore plus limited rights holders)
off refers to the "offshore" quota (commercial less limited rights holders)
T refers to total or global, i.e. results are summed over all five super-areas (can refer to any combination of comm., off, recreational etc).

Catch related statistics:

C_{ave}^{comm} : the 10-year average (2006-2015) annual commercial catch in MT for each super-area.

C_{ave}^{off} : the 10-year average (2006-2015) annual offshore catch in MT for each super-area.

$REC^{T}(t)$ the total (i.e. sum over all 5 super-areas) recreational take for year *t*.

$TAC_{07-09}^{T,comm}$ the average total (i.e. sum over all 5 super-areas) commercial TAC for the first three years (2007, 2008 and 2009).

$TAC_{07-09}^{T,off}$ the average total (i.e. sum over all 5 super-areas) offshore TAC for the first three years (2007, 2008 and 2009).

$TAC_{06-15}^{T,comm}$ the average total (i.e. sum over all 5 super-areas) annual commercial TAC for the full ten years (2006 - 2015).

$TAC_{06-15}^{T,off}$ the average total (i.e. sum over all 5 super-areas) annual offshore TAC for the full ten years (2006 - 2015).

V^{comm} : the 10-year (2006-2015) average inter-annual commercial catch variation for each super-area.

V^{off} : the 10-year (2006-2015) average inter-annual offshore catch variation for each super-area.

Biomass related statistics:

$B_{75,m+f}$ refers to the biomass of male and female lobsters above 75mm for each super-area

$B_{75,m+f}^{T}$ refers to the biomass of male and female lobsters above 75mm for all five super-areas combined

$B_{75,m}$ refers to the biomass of male only lobsters above 75mm for each super-area

$B_{75,m}^{T}$ refers to the biomass of male only lobsters above 75mm for all five super-areas combined

$B_{60,f}$ refers to the biomass of female lobsters above 60mm for each super-area

$B_{60,f}^{T}$ refers to the biomass of female lobsters above 60mm for all five super-areas combined

Results are reported as ratios for 2016/2006 and 2016/1980 and 2016.1910.

Comparative *B*(16/06) results assuming the resource is managed using a future CC = zero harvesting strategy are also produced.

<u>Effort related statistics</u>

Effort(y/06) the trap effort in season y compared to that in 2006. Here Effort(y) is calculated as the total trap catch in season y, divided by the trap CPUE from super-areas A7 and A8 (weighted according to the method described above).

Note that for each statistic, the median and the 5th and 96th %iles are reported. The 5th and 96th percentiles are estimated by fitting a regression line through the 13th - 18th values, and the 284th - 288th values respectively of the ordered set of results from 300 replicates, and using the midpoints as the final 5th and 95th percentiles. This method is implemented in order to aid smoothing of distributions in circumstances where sudden jumps may occur as scenarios switch over the 300 possibilities.

TAC (commercial), $B_{75,m}$ and Effort(y/06) trajectories are also presented for each super-area.

9. OMP TAC setting rule

For results presented here, the following TAC algorithm is used to calculate the global (commercial + recreational all super-areas) TAC (TAC_y^G):

$$TAC_y^G = w_y TAC_{y-1}^G + (1-w_y)\alpha\left(\frac{\beta_{y-3,y-2,y-1}}{\bar{\beta}_{89-04}}\right)^{\lambda}\left(\frac{\hat{B}_y}{\hat{B}_{1992}}\right) \quad x$$

$$\left[f_1\left(\frac{CPUE_{y-1,y-2,y-3}^{trap}}{CPUE_{93,94,95}^{trap}}\right) + f_2\left(\frac{CPUE_{y-1,y-2,y-3}^{hoop}}{CPUE_{93,94,95}^{hoop}}\right) + (1-f_1-f_2)\left(\frac{FIMS_{y-3,y-2,y-1}}{FIMS_{92,93,94,95}}\right)\right]^p$$

where (1)

$w_y = 0.50$ for all years,

$p = 0.5$,

$f_1 = 0.40$;

$f_2 = 0.20$; and

α is the primary tuning parameter.

Note that β refers to the somatic growth rate of a 70mm male lobster, and that $\bar{\beta}_{89-04}$ refers to the geometric mean β over the 1989-2004 period. Note that it is the factor in Eqn (1) related to the β parameters that is modified under section 2 below). The choice of parameter values for the final term means a TRAP:HOOP:FIMS weigthing of 0.4:0.4:0.2.

Estimation of $\hat{B}_t$ *and* $\hat{B}_{1992}$

The underlying approach followed will be to fit a simple population model to available $CPUE^{trap}$, $CPUE^{hoop}$, *FIMS* and somatic growth data to model the dynamics from 1992 to *t*-1, the most recent year for which data are available, i.e.:

$$B_{T+1}^{p} = B_{T}^{p} + G_{T} - (C_{T} + P_{T}) \qquad (2)$$

where

B_{T}^{p} = population model biomass in year *T*,

G_T = annual “growth” of resource in year *T*,

C_T = annual commercial + recreational catch in year *T*, and

P_T = annual estimate of poaching for year *T*.

B_{1992}^{p} is a parameter estimated in fitting this model to the data.

The annual somatic growth rate parameter β_T is the moult-probability model (OLRAC 2005) estimated somatic growth of a male rock lobster of 70mm carapace length. For any year *t* for which a TAC is required, β_T is known for all preceding years.

In the population model, the annual “growth” of the resource, G_T, is set to be:

$$G_{T} = a(\beta_{T} + b) \qquad (3)$$

The value of *b* is set externally by regressing against β the equilibrium sustainable yield for the RC1, ALTL and ALTH assessment model’s estimates of the biomass in 2005 (for the case where all the super-area are considered together) for different values of β (this relationship is near linear). The intercept of this regression with the horizontal axis (β), averaged over these three area-aggregated assessments, yields a value of *b* = -2.5636 for use in equation (3).

Each season (from *t* = 2007), as new data become available, the population model (see equation 1) is fitted by minimising the following negative log-likelihood:

$$-\ln L = \sum_{T=1993}^{t-1}\left\{\ln\sigma_{CPUE^{trap}} + \frac{1}{2\sigma^2_{CPUE^{trap}}}\left(\ln CPUE_T^{trap} - \ln q_{CPUE^{trap}} - \ln B_T^P\right)^2\right\}$$
$$+ \sum_{T=1993}^{t-1}\left\{\ln\sigma_{CPUE^{hoop}} + \frac{1}{2\sigma^2_{CPUE^{hoop}}}\left(\ln CPUE_T^{hoop} - \ln q_{CPUE^{hoop}} - \ln B_T^P\right)^2\right\} \quad (4)$$
$$+ \sum_{T=1992}^{t-1}\left\{\ln\sigma_{FIMS} + \frac{1}{2\sigma^2_{FIMS}}\left(\ln FIMS_T - \ln q_{FIMS} - \ln B_T^P\right)^2\right\}$$

where

$CPUE_T^{trap}$	is the trap CPUE for year T
$CPUE_T^{hoop}$	is the hoop CPUE for year T
$FIMS_T$	is the FIMS CPUE for year T
$q_{CPUE^{trap}}$	is the trap catchability coefficient
$q_{CPUE^{hoop}}$	is the hoop catchability coefficient
q_{FIMS}	is the FIMS catchability coefficient

$$\ln q_{CPUE^{trap}} = \frac{\sum_{T=1993}^{t-1}\left(\ln CPUE_T^{trap} - \ln B_T^P\right)}{n_{CPUE^{trap}}} \quad (5)$$

$$\ln q_{CPUE^{thoop}} = \frac{\sum_{T=1993}^{t-1}\left(\ln CPUE_T^{hoop} - \ln B_T^P\right)}{n_{CPUE^{hoop}}} \quad (6)$$

$$\ln q_{FIMS} = \frac{\sum_{T=1992}^{t-1}\left(\ln FIMS_T - \ln B_T^P\right)}{n_{FIMS}} \quad (7)$$

$$\sigma_{CPUE^{trap}} = \sqrt{\frac{\sum_{T=1993}^{t-1}\left(\ln CPUE_T^{trap} - \ln q_{CPUE^{trap}} - \ln B_T^P\right)^2}{n_{CPUE^{trap}}}}, \quad (8)$$

$$\sigma_{CPUE^{hoop}} = \sqrt{\frac{\sum_{T=1993}^{t-1}\left(\ln CPUE_T^{hoop} - \ln q_{CPUE^{hoop}} - \ln B_T^P\right)^2}{n_{CPUE^{hoop}}}}, \quad (9)$$

$$\sigma_{FIMS} = \sqrt{\frac{\sum_{T=1992}^{t-1}\left(\ln FIMS_T - \ln q_{FIMS} - \ln B_T^P\right)^2}{n_{FIMS}}} \quad (10)$$

The parameters of the likelihood L estimated in the fitting process are B_{1992}^P and a.

A penalty function is added to the negative log-likelihood function for the "a" parameter of the G_T relationship (equation 3) used. The penalty function is as follows:

$$P = \frac{(a-3000)^2}{2\sigma_a^2}$$

where $\sigma_a = 1000$.

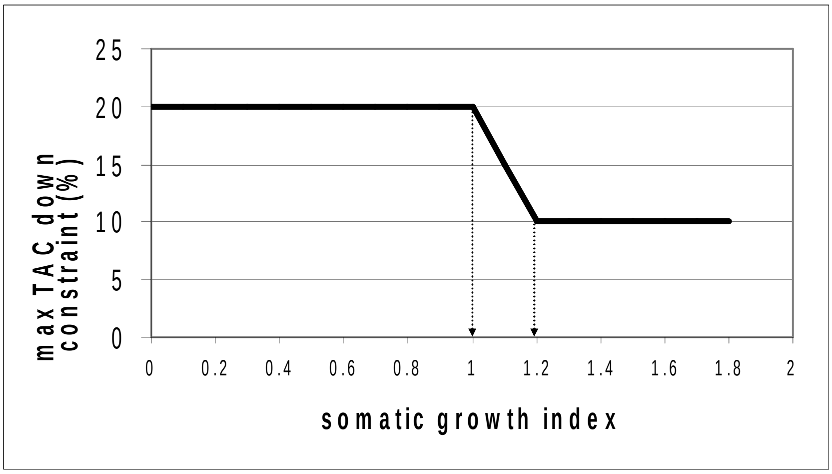
Thus, equation (4) becomes:

$$-\ln L = \sum_{T=1993}^{t-1}\left\{\ln\sigma_{CPUE^{trap}} + \frac{1}{2\sigma^2_{CPUE^{trap}}}\left(\ln CPUE_T^{trap} - \ln q_{CPUE^{trap}} - \ln B_T^P\right)^2\right\}$$
$$+ \sum_{T=1993}^{t-1}\left\{\ln\sigma_{CPUE^{hoop}} + \frac{1}{2\sigma^2_{CPUE^{hoop}}}\left(\ln CPUE_T^{hoop} - \ln q_{CPUE^{hoop}} - \ln B_T^P\right)^2\right\}$$
$$+ \sum_{T=1992}^{t-1}\left\{\ln\sigma_{FIMS} + \frac{1}{2\sigma^2_{FIMS}}\left(\ln FIMS_T - \ln q_{FIMS} - \ln B_T^P\right)^2\right\} + P$$

A number of further modifications have been made to the above OMP. Their aim is particularly to react to reduce catches sufficiently if especially poor resource signals are forthcoming. These are as follows.

i. Maximum (global) TAC downward inter-annual constraint

A maximum TAC downward inter-annual constraint of 10% is assumed for the first two years (2007 and 2008). From 2009 onwards, this constraint is modified according to the value of the somatic growth rate index ($\frac{\bar{\beta}_{y-3,y-2,y-1}}{\bar{\beta}_{89-04}}$), where $\bar{\beta}_{\{y\}}$ indicates the average value of β over the years in $\{y\}$ as follows:



Thus for years 2009+ the maximum TAC downward constraint is allowed to range from 10%-20%.

Note: A maximum global TAC upward constraint of 10% is imposed for all years.

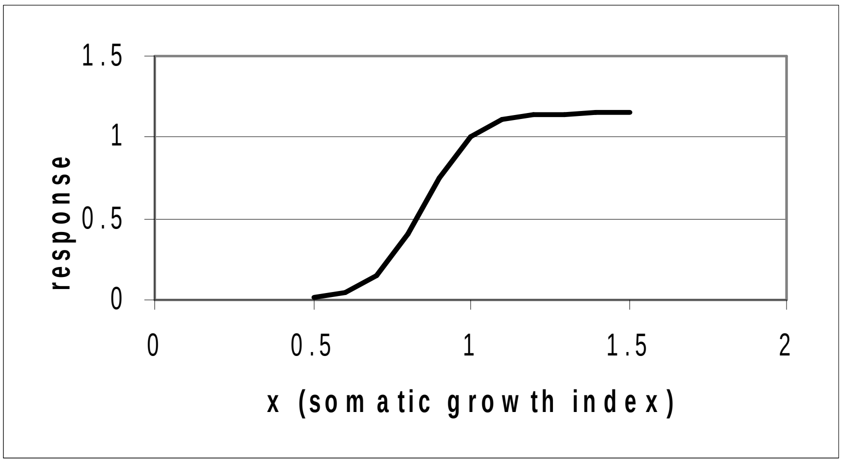
ii. Modified response to somatic growth changes

If $x = \dfrac{\overline{\beta}_{y-3,y-2,y-1}}{\overline{\beta}_{89-04}}$, then the response to the somatic growth rate index in the OMP was initially given by x^{λ} (see Eqn (1)), with λ set at 1 so this term varies linearly with recent somatic growth rate.

The OMP now incorporates a more sharply changing response for *x* (in the sense that the TAC drops more sharply for values of *x* < 1), which is as follows:

x^{λ} changed to $\dfrac{1+P_1}{1+P_1 e^{-(x-P_2)/P_3}}$

For values $P_1 = 0.15$, $P_2 = 1.0$ and $P_3 = 0.08$ (which were selected for optimal OMP performance), the following somatic growth rate response function then applies:



iii. Geometric averages

The OMP has been modified so that when taking averages of the input data in the OMP calculations (see STEP 2 on page 7), the geometric mean was used instead of the arithmetic mean. This change was hoped to reduce the extent of variation in results, which arose from some exceptionally large input data points in particular years for some of the simulations.

iv. Capping of input data

A maximum inter-annual increase in any one of the input indices from each super-area (prior to the combining over all five areas into a single index as input into the OMP) is imposed. The reason is that for some simulations, due to very large variances (σ values) being used to generate the “real” data for use in the OMP, some VERY large CPUE or FIMS values can occur. As these indices are a representation of either the fishable biomass (the trap and hoop CPUE) or the 60+ biomass (FIMS), it is not plausible that in reality, in one year, these biomasses could suddenly increase by (say) 4 or 5 times. It was thus decided to put a plausibility cap on any input index value (from any of the 5 super-areas) which was greater then 4 time the **average** of the previous 5 years' values.

A second form of "capping": here the "cap" is placed on the operating model's generated CPUE input data. After examining the standardised residuals of the RC model fit to trap CPUE, hoop CPUE and FIMS CPUE, it seemed that there was a case for capping the amount of noise added to the generated input data values on the basis of limiting added errors to about the maximum evident in earlier observations. For example, in generating the trap CPUE as follows:

$$CPUE_y^{trap,area,sim} = \hat{q}^{trap,area} B_y^{\exp,area} e^{\varepsilon_{y,area}} \qquad \varepsilon_{y,area} \sim N(0, \sigma^2_{trap,area})$$

a cap would be placed on the ε such that
if $\varepsilon > 1.8$ $\quad \varepsilon = 1.8$
if $\varepsilon < -2.0$ $\quad \varepsilon = -2.0$

v. Limited rights holders quotas

A total of 560 MT is to be set aside for quota for the Limited Rights holders. The areal breakdown of this quota is as follows:
A1-2 = 30 MT
A3-4 = 90 MT
A5-6 = 40 MT
A7 = 0 MT
A8 = 400 MT
The OMP thus ensures these values to be minimum super-area TAC values for each year in the future.

For A1-2 and A5-6, only quota for limited rights holders will be allocated; thus these two super-area essentially have fixed future TACs at 30 MT and 40 MT respectively. Due to the fact therefore, that these two super-areas do not require an OMP to generate any further commercial TAC, they have been "removed" from the OMP-calculations. Future input data required by the OMP will thus be from super-areas A3-4, A7 and A8 only.

vi. Transfer of TAC from A8 to A3-4 and A7

An amount of 5% of the A8 TAC is transferred to A3-4 and A7 in the ratio 0.3:0.7. This transfer is due to the fact the OMP tends to generate slightly too much TAC for A8, and to under-utilise A3-4 and A7.

vii. 2005 somatic growth input into OMP

The moult probability model was recently updated to include data for 2005. Although these data are not used in the underlying assessment models, they are used as input into the OMP projections (instead of using model-generated data).

Summary of order of TAC calculations

1. OMP generates the global (all super-areas combined) commercial(offshore+limited rights holders)+recreational TAC
2. Check for inter-annual TAC constraint violations (at global level)
3. Remove the total recreational TAC (which will then be split into super-areas for subsequent computations)
4. Re-check that the remaining commercial (offshore+limited rights holders) global TAC does not violate inter-annual TAC constraints
5. Split this global commercial TAC into super-areas
6. Ensure that the limited rights holders allocations for the TAC are possible for each super-area (if not – need to re-shuffle TAC across areas)
7. Transfer 5% of commercial TAC from A8 to A34 and A7.

References

OLRAC. 2005. Updated male somatic growth rate estimates for input into the spatially disaggregated assessment for West Cost rock lobsters. MCM document, WG/09/05/WCRL17.

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