# Further area-disaggregated OMP results for the west coast rock lobster resource

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## 1. Replacement Yield calculations

At the request of the working group, two replacement yield (RY) estimates have been produced, using the area-disaggregated modelling framework. These RY estimates are the commercial TAC which can be taken each year in the future to ensure the total male biomass remains at current levels, i.e. that $B_m^T$ (16/06) = 1.0. In addition commercial RY estimates, it is assumed 320 MT will be taken recreationally, and that 500 MT will be taken by poaching. The two RY estimates differ with respect to the assumptions regarding the future somatic growth rate. The first RY is calculated assuming the full range of integrated values of somatic growth – that is a relative ratio of 50:40:10 of low, medium and high future somatic growth rate scenarios to eventuate. The second RY assumes that only the low somatic growth scenario will occur in the future.

RY (full somatic growth integration) = 2734 MT
RY (low somatic growth only in the future) = 2088 MT.

## 2. Candidate OMPs

The new OMP uses data (trap and hoop CPUE, FIMS, somatic growth rate) from super-areas 3-4, 7 and 8, 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. Super-areas A1-2 and A5-6 are not included in this process for reasons set out in i) below. 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 to be taken each year.

The candidate OMP presented here is described in full in Appendix 1. It is virtually identical to that presented in WG/12/06/WCRL34. Some new features are as follows:

### i) 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.

**ii) Transfer of TAC from A8 to A3-4**

An amount of 2% of the A8 TAC is transferred to A3-4 (previously the transfer was to A3-4 and A5-6). This transfer is due to the fact the OMP tends to generate slightly too much TAC for A8, and be under-utilise A3-4.

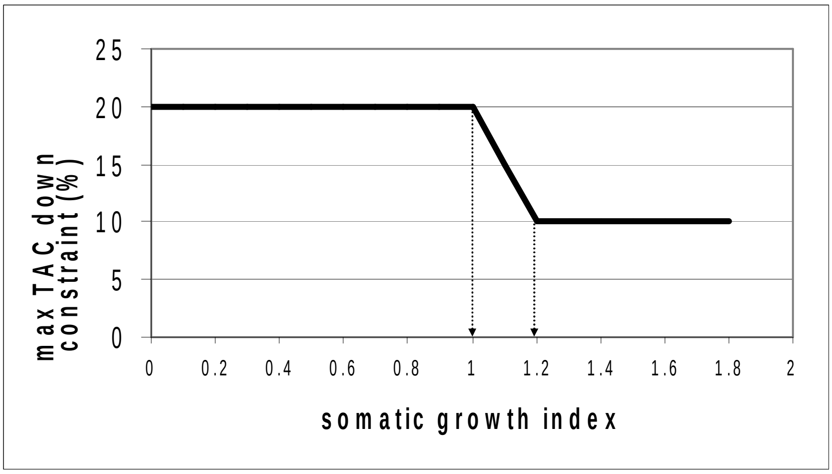
Other features of the OMP that remain are:

**iii) Integration of the summary output statistics**

Note that for each statistic, the median and the 5$^{th}$ and 96$^{th}$ %iles are reported. The 5$^{th}$ and 96$^{th}$ percentiles are estimated by fitting a regression line through the 13$^{th}$ - 18$^{th}$ values, and the 284$^{th}$ - 288$^{th}$ values respectively of the ordered set of results from 3000 replicates, and using the midpoints as the final 5$^{th}$ and 95$^{th}$ percentiles. This method is implemented in order to aid smoothing of distributions in circumstances where sudden jumps may occur as scenarios switch within the 300 replicates.

**iv) Maximum TAC downward inter-annual constraint**

The maximum TAC downward inter-annual constraint of 10% is assumed for the first three years (2006, 2007, 2008). From 2009 onwards, this constraint is modified according to the value of the somatic growth rate index ($\frac{\beta_{y-3,y-2,y-1}}{\bar{\beta}_{89-04}}$) as follows:



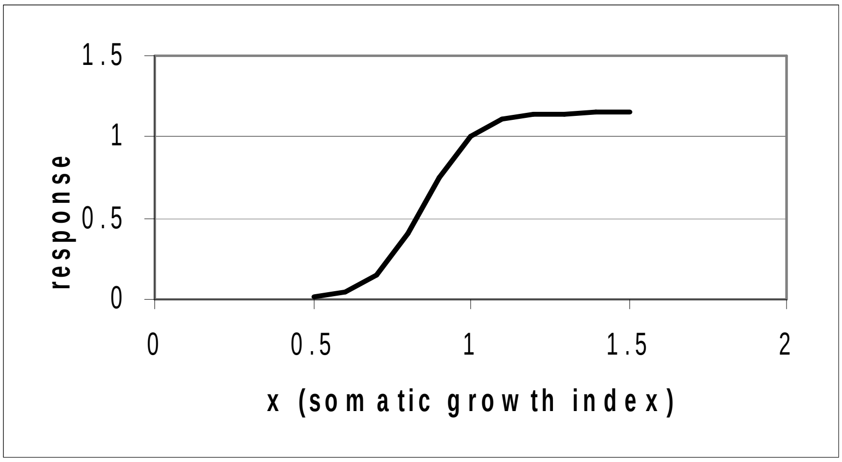

Thus for years 2009+ the maximum TAC downward constraint is allowed to range from 10%-20%.

**v) Alternate response to somatic growth changes**

If $x = \frac{\beta_{y-3,y-2,y-1}}{\bar{\beta}_{89-04}}$, then the response to the somatic growth rate index in the OMP formula (Eqn 1 of Appendix 1) incorporates a more sharply changing response for *x*, which is as follows:

$$\text{Response} = \frac{1+P_1}{1+P_1 e^{-(x-P_2)/P_3}}$$

For example, for the values $P_1 = 0.15,\ P_2 = 1.0$ and $P_3 = 0.08$ currently used, the following somatic growth rate response function applies:




**vi) Decrease weight of FIMS data in OMP**

The weights given to the TRAP:HOOP:FIMS data (the f factors in Eqn 1 of Appendix 1) are 0.4:0.4:0.2.

## 3. OMP candidate results

A wide variety of variants of the OMP of Appendix 1 were evaluated. The aim of the variations was to try and produce narrower probability intervals for the resource recovery statistics (*B*(16/06) values). Variations that were attempted include:

- Alternate values of $f_1$ and $f_2$ (relative weighting factors for trap, hoop and FIMS CPUE in the OMP)
- Alternate values of *p* (see Eqn 1 in Appendix 1)
- Alternate levels of “capping” of input data (see Appendix 1, section 5)
- Alternate forms of the somatic growth “response” term in Eqn 1
- Limits on the extent of large inter-annual changes in the input indices, which would seem implausible
- Maintaining future somatic growth rate constant (and removing the somatic growth term from OMP) in an attempt to improve the OMP performance based on future recruitment variability only.

Appendix 2 reports results (in the form of *B*(16/06) summary statistics) for a range of empirical OMPs which were explored. These OMPs were tuned assuming future somatic growth rate remains low. The purpose was to determine if a more simple, i.e.

empirical type OMP could be made to perform adequately or even better that the proposed candidate OMP.

Results presented in Table 1 are for the full stochastic integration, and where all OMPs have been tuned so that the median global commercial TAC over the 10 year projection period is 2200 MT.

Table 1 presents results of the most successful OMPs. OMP1 is as described in Appendix 1. OMP2 is identical to OMP1, except that the average of the somatic growth rate index is extended to include the last five years (in contrast to last three years).

Table 1 also presents results for a constant (commercial) catch of 2200 MT, which assumes the following super-area breakdown:

A1-2 = 30 MT
A3-4 = 230 MT
A5-6 = 40 MT
A7 = 590 MT
A8 = 1310 MT

Table 2 reports results for OMP2 which has been run assuming the future somatic growth in the future is always low.

Table 3 reports results for OMP2 for three alternate tunings – for either 2000 MT, 2200 MT or 2400 MT 10-year average commercial TACs.

## 4. Discussion

**Implication of "fixed" TACs for A1-2 and A5-6.**
A1-2 and A5-6 will essentially have fixed TACs at 30 MT and 40 MT respectively, which will be allocated to limited rights holders. The implications of this are that the median *B*(16/06) recovery statistics are estimated to be 0.78 for A1-2 and 1.77 for A5-6 (for the full stochastic simulation). If low growth only is assumed for the future, these statistics are then still 0.78 for A1-2 (no change in somatic growth for A1-2 is in any case assumed), and 1.52 for A5-6. It must be born in mind though that in 2005 A5-6 is estimated to be nearly depleted (see Table 5), so that some increase is essential.

**Performace of empirical-based OMPs**
The results presented in Appendix 2 show that the simple empirical OMPs examined resulted in even wider PIs on the *B*(16/06) statistic, and produced some very low $5^{th}$%iles for A8 (e.g. 0.21 for OMP D – see Table A2.1). The more complicated model-based OMP appears to perform the best.

**Performace of model-based OMPs: OMP1 and OMP2**
The advantage of using an OMP compared to simply fixing TAC at a constant level is shown in Table 1 and Figure 1. The PIs associated with the OMPs for the *B*(16/06) statistic are narrower – due to the fact that the OMP modifies the TAC in response to either good or poor performance of the resource which it determines from the input

data from the various super-areas though the extent of this improvement is less than one might wish (the extent of noise in the data precludes better performance).

Much effort was expended in trying to improve the performance of OMP1 – particularly with respect to the low 5%ile of the super-area A8 *B*(16/06) value of 0.47. OMP2, which is identical to OMP1 except that is uses a five year average in the somatic growth index in contrast to a three year average, does improve the overall performance both with respect to larger 5%ile *B*(16/06) values, as well as slightly narrowing the PIs for the average commercial TAC (see Table 1).

Running both OMP1 and OMP2 assuming a constant low somatic growth in the future, OMP2 once again performs the best with respect to the *B*(16/06) statistics – see Table 2.

What Table 2 demonstrates, is what will happen if OMP is selected which has been tuned on the full stochastic integration, for say a median 1.22 total resource recovery (*B*(16/06), if in fact, the low growth scenario eventuates. OMP1 would result in a median total *B*(16/06) of 1.00, whereas OMP2 would result in a median value of 1.05. In these circumstances, OMP2 will also result in larger median *B*(16/06) values for A3-4, A7 and A8, and also higher 5%iles. Note that in median terms, A8 drops by 20% under OMP2, which at least is better than the 30% under OMP1.

**Alternate levels of tuning**

The OMPs presented in Table 1 were tuned so that for the full stochastic integration, the average commercial TAC over the 10-year projection period would be (about) 2200 MT. Table 3 reports results for OMP2 for which two further tuning are reported: 2000 MT and 2400 MT average commercial TACs. One could also produce tunings for specific *B*(16/06) levels, and one could further produce tunings assuming the low somatic growth rate occurs in the future.

## 5. Comparison with OMP(2003)

When developing the currently in place OMP – OMP(2003), the 80% probability intervals (PIs) of various summary statistics were examined. Currently the 90% probability intervals are being examined in developing the new area-disaggregated OMP. An interesting question is obviously, what were the PIs associated with the current OMP(2003) compared to those of the OMPs under development. Table 4 compares the median and 80% PIs of OMP1 and that of OMP(2003) for the biomass recovery statistic. For OMP(2003) this was *B*(13/03), whereas for OMP1, this statistic is *B*(16/06); the PI for the latter is somewhat improved.

## 6. Future work

At this stage it appears that OMP2 should be selected as a baseline candidate OMP. Further work requires:

i) experimentation with variants of some of the control parameters seeking improved behaviour (though there seems little scope likely for this);
ii) agreement of a set of robustness trials, and testing OMP2 performance against these.

## Reference List

Johnston, S.J. and D.S. Butterworth. 2006. Some preliminary results for initial OMP options. MCM document, WG/12/06/WCRL34.

Table 1: Median and 5th and 95th percentile values for two candidate OMPs as well as for a CC option. Results are for the full stochastic integration.

| | | **CC = 2200 MT** | **OMP1**<br>3 yr ave in s.g. index<br>$\alpha$ =3900 | **OMP2**<br>5 yr ave in s.g. index<br>$\alpha$ =3400 |
|---|---|---|---|---|
| **Ave TAC commercial** | A1-2 | 30 [30; 30] | 30 [30; 30] | 30 [30; 30] |
| | A3-4 | 230 [230; 230] | 234 [169; 385] | 233 [167; 378] |
| | A5-6 | 40 [40; 40] | 40 [40; 40] | 40 [40; 40] |
| | A7 | 590 [590; 590] | 602 [352; 907] | 599 [351; 891] |
| | A8 | 1310 [1310; 1310] | 1309 [1032; 1991] | 1292 [1029; 1899] |
| | T | 2200 [2200; 2200] | 2206 [1758; 3233] | 2195 [1727; 3192] |
| **Ave TAC offshore** | A1-2 | 0 [0; 0] | 0 [0; 0] | 0 [0; 0] |
| | A3-4 | 140 [140; 140] | 144 [80; 294] | 143 [77; 288] |
| | A5-6 | 0 [0; 0] | 0 [0; 0] | 0 [0; 0] |
| | A7 | 590 [590; 590] | 602 [352; 907] | 599 [351; 891] |
| | A8 | 910 [910; 910] | 909 [632; 1592] | 892 [629; 1499] |
| | T | 164 [1640; 1640] | 1615 [1168; 2642] | 1605 [1138; 2602]] |
| **Ave V commercial** | A1-2 | 0 [0; 0] | 0 [0; 0] | 0 [0; 0] |
| | A3-4 | 0 [0; 0] | 17 [12; 23] | 17 [12; 24] |
| | A5-6 | 0 [0; 0] | 0 [0; 0] | 0 [0; 0] |
| | A7 | 0 [0; 0] | 13 [7; 21] | 12 [7; 21] |
| | A8 | 0 [0; 0] | 9 [6; 13] | 9 [5; 13] |
| | T | 0 [0; 0] | 8 [5; 11] | 8 [5; 11] |
| **$B_m$(16/06)** | A1-2 | 0.77 [0.48; 1.31] | 0.79 [0.50; 1.31] | 0.78 [0.50; 1.31] |
| | A3-4 | 1.00 [0.55; 2.56] | 0.95 [0.55; 2.43] | 0.95 [0.55; 2.44] |
| | A5-6 | 1.75 [0.58; 11.26] | 1.76 [0.63; 11.28] | 1.77 [0.63; 11.28] |
| | A7 | 1.29 [0.42; 3.44] | 1.33 [0.44; 3.36] | 1.34 [0.53; 3.44] |
| | A8 | 0.96 [0.21; 2.86] | 0.99 [0.47; 2.57] | 1.00 [0.50; 2.63] |
| | T | 1.24 [0.53; 2.98] | 1.22 [0.69; 2.83] | 1.23 [0.70; 2.84] |

Table 2: Median and 5th and 95th percentile values for the same scenarios as reported in Table 1. Results here are calculated assuming all future somatic growth rates are follow the low scenario.

| | | **CC = 2200 MT** | **OMP1**<br>3 yr ave in s.g. index<br>$\alpha$ =3900 | **OMP2**<br>5 yr ave in s.g. index<br>$\alpha$ =3400 |
|---|---|---|---|---|
| **Ave TAC commercial** | A1-2 | 30 [30; 30] | 30 [30; 30] | 30 [30; 30] |
| | A3-4 | 230 [230; 230] | 226 [171; 306] | 211 [161; 288] |
| | A5-6 | 40 [40; 40] | 40 [40; 40] | 40 [40; 40] |
| | A7 | 590 [590; 590] | 610 [358; 846] | 571 [341; 799] |
| | A8 | 1310 [1310; 1310] | 1300 [1018; 1649] | 1215 [960; 1527] |
| | T | 2200 [2200; 2200] | 2188 [1798; 2693] | 2065 [1690; 2616] |
| **Ave TAC offshore** | A1-2 | 0 [0; 0] | 0 [0; 0] | 0 [0; 0] |
| | A3-4 | 140 [140; 140] | 136 [81; 216] | 121 [70; 198] |
| | A5-6 | 0 [0; 0] | 0 [0; 0] | 0 [0; 0] |
| | A7 | 590 [590; 590] | 610 [358; 846] | 571 [341; 799] |
| | A8 | 910 [910; 910] | 900 [618; 1249] | 815 [560; 1127] |
| | T | 164 [1640; 1640] | 1598 [1203; 2103] | 1476 [1100; 1927] |
| **Ave V commercial** | A1-2 | 0 [0; 0] | 0 [0; 0] | 0 [0; 0] |
| | A3-4 | 0 [0; 0] | 16 [12; 21] | 15 [11; 20] |
| | A5-6 | 0 [0; 0] | 0 [0; 0] | 0 [0; 0] |
| | A7 | 0 [0; 0] | 13 [8; 21] | 12 [7; 22] |
| | A8 | 0 [0; 0] | 9 [6; 13] | 9 [5; 13] |
| | T | 0 [0; 0] | 9 [6; 12] | 9 [5; 12] |
| **$B_m$(16/06)** | A1-2 | 0.77 [0.48; 1.31] | 0.79 [0.51; 1.32] | 0.79 [0.51; 1.32] |
| | A3-4 | 0.87 [0.46; 1.92] | 0.83 [0.49; 1.91] | 0.87 [0.53; 1.93] |
| | A5-6 | 1.50 [0.51; 8.43] | 1.52 [0.56; 8.47] | 1.54 [0.56; 8.49] |
| | A7 | 1.22 [0.35; 3.25] | 1.23 [0.50; 3.16] | 1.33 [0.55; 3.28] |
| | A8 | 0.63 [0.16; 1.37] | 0.69 [0.34; 1.40] | 0.79 [0.44; 1.57] |
| | T | 0.95 [0.43; 2.07] | 1.00 [0.54; 2.11] | 1.05 [0.64; 2.19] |

Table 3: Median and 5th and 95th percentile values OMP2 for three alternate tunings. Results are for the full stochastic integration.

| | | **2000 MT tuning** $\alpha$ **= 2750** | **2200 MT tuning** $\alpha$ **=3400** | **2400 MT tuning** $\alpha$ **= 4350** |
|---|---|---|---|---|
| **Ave TAC commercial** | A1-2 | 30 [30; 30] | 30 [30; 30] | 30 [30; 30] |
| | A3-4 | 207 [153; 332] | 233 [167; 378] | 263 [188; 423] |
| | A5-6 | 40 [40; 40] | 40 [40; 40] | 40 [40; 40] |
| | A7 | 543 [330; 798] | 599 [351; 891] | 663 [382; 1019] |
| | A8 | 1188 [959; 17127] | 1292 [1029; 1899] | 1426 [1132; 2105] |
| | T | 2005 [1627; 2888] | 2195 [1727; 3192] | 2410 [1884; 3518] |
| **Ave TAC offshore** | A1-2 | 0 [0; 0] | 0 [0; 0] | 0 [0; 0] |
| | A3-4 | 117 [63; 242] | 143 [77; 288] | 173 [98; 334] |
| | A5-6 | 0 [0; 0] | 0 [0; 0] | 0 [0; 0] |
| | A7 | 543 [330; 798] | 599 [351; 891] | 663 [382; 1019] |
| | A8 | 788 [599; 1327] | 892 [629; 1499] | 1026 [732; 1765] |
| | T | 1415 [1037; 2298]] | 1605 [1138; 2602]] | 1822 [1294; 2928]] |
| **Ave V commercial** | A1-2 | 0 [0; 0] | 0 [0; 0] | 0 [0; 0] |
| | A3-4 | 16 [11; 22] | 17 [12; 24] | 18 [14; 25] |
| | A5-6 | 0 [0; 0] | 0 [0; 0] | 0 [0; 0] |
| | A7 | 13 [8; 22] | 12 [7; 21] | 12 [7; 21] |
| | A8 | 9 [6; 13] | 9 [5; 13] | 9 [5; 12] |
| | T | 8 [5; 12] | 8 [5; 11] | 8 [6; 11] |
| $\boldsymbol{B_m}$**(16/06)** | A1-2 | 0.79 [0.51; 1.33] | 0.78 [0.50; 1.31] | 0.78 [0.50; 1.31] |
| | A3-4 | 1.00 [0.60; 2.49] | 0.95 [0.55; 2.44] | 0.89 [0.49; 2.35] |
| | A5-6 | 1.78 [0.64; 11.30] | 1.77 [0.63; 11.28] | 1.75 [0.61; 11.26] |
| | A7 | 1.44 [0.63; 3.56] | 1.34 [0.53; 3.44] | 1.20 [0.37; 3.24] |
| | A8 | 1.15 [0.62; 2.83] | 1.00 [0.50; 2.63] | 0.82 [0.30; 2.42] |
| | T | 1.33 [0.79; 2.94] | 1.23 [0.70; 2.84] | 1.08 [0.60; 2.69] |

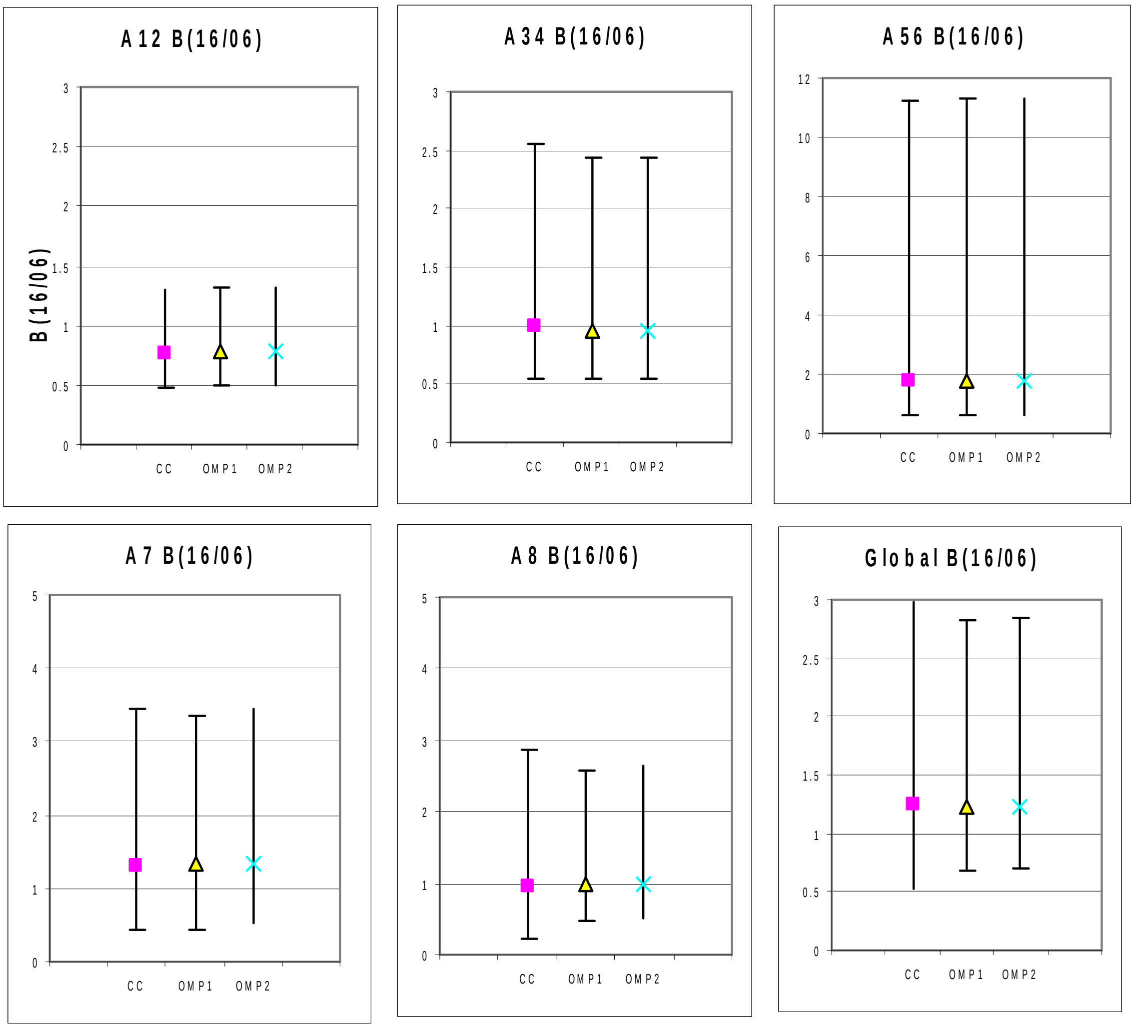
Table 4: Comparison of the median and 80% probability intervals for the resource recovery statistic between OMP(2003) and those for OMP1.

| | **OMP1 $B_m$(16/06)** | **OMP(2003) $B_m$(13/03)** |
|---|---|---|
| A1-2 | 0.79 [0.55; 1.14] | - |
| A3-4 | 0.95 [0.60; 1.95] | - |
| A5-6 | 1.76 [0.76; 7.45] | - |
| A7 | 1.33 [0.74; 2.81] | - |
| A8 | 0.99 [0.56; 1.92] | - |
| T | 1.22 [0.76; 2.30] | 1.15 [0.67; 2.50] |

Table 5: $B^{75}$(2006/1910) values for each super-area. Results presented for the best estimate for $R_{2000}$ (RC), as well as for the two alternate assessment models (ALTL and ALTH).

| | **B(2005) MT** | **B(2005/1910)** |
|---|---|---|
| **A1-2** | **708** | **0.019** |
| **A3-4** | **4857** | **0.032** |
| **A5-6** | **2090** | **0.014** |
| **A7** | **5199** | **0.024** |
| **A8** | **9200** | **0.057** |

Figure 1: Median *B*(16/06) with 90% PIs for CC=2200 MT, OMP1 and OMP2. Results are for the full stochastic integration.



## Appendix 1: Description of the OMP currently being developed

For results presented here, the following TAC algorithm (with one modification detailed in section 2.1 below) is used to calculate the global (commercial + recreational all super-areas) TAC ($TAC_y^G$):

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

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

where (1)

$w_y$ = 0.50 for all years,

$p$ = 0.5,

$f_1$ = 0.40;

$f_2$ = 0.20; and

$\alpha$ is the primary tuning parameter.

Note that $\beta$ refers to the somatic growth rate of a 70mm male lobster, and that $\overline{\beta}_{89-04}$ refers to the average $\beta$ over the 1989-2004 period. Note that it is the factor in Eqn (1) related to the $\beta$ parameters that is modified under section 2 below).

### *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.:

$$B^p_{T+1} = B^p_T + G_T - (C_T + P_T) \quad (2)$$

where

$B^p_T$ = 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*.

$B^p_{1992}$ is a parameter estimated in fitting this model to the data.

The annual somatic growth rate parameter $\beta_T$ 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, $\beta_T$ is known for all preceding years.

In the population model, the annual "growth" of the resource, $G_T$, is set to be:

$$G_T = a(\beta_T + b) \tag{3}$$

The value of *b* is set externally by regressing against $\beta$ 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 $\beta$ (this relationship is near linear). The intercept of this regression with the horizontal axis ($\beta$), averaged over these three area-aggregated assessments, yields a value of $b$ = -2.5636 for use in equation (3).

Each season (from $t$ = 2006), as new data become available, the population model (see equation 1) is fitted by minimising the following negative log-likelihood:

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

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 |

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

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

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

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

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

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

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 initially $\sigma_a = 1000$.

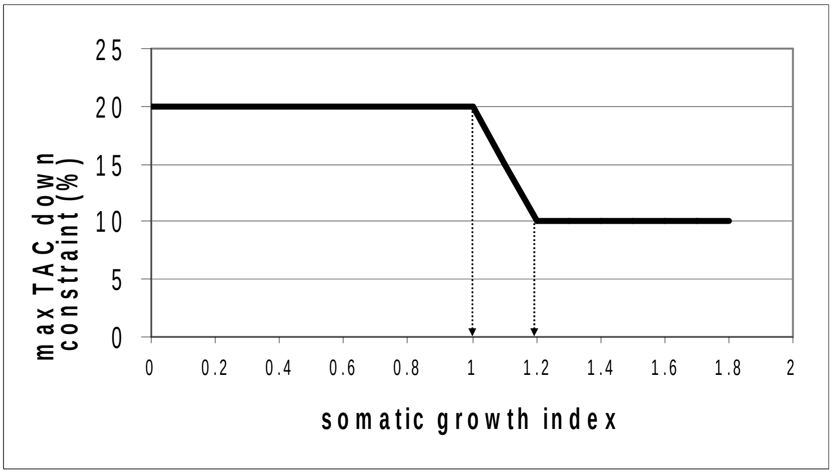
Thus, equation (4) becomes:

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

A number of further modifications were made to the initial OMP as set out in Johnston and Butterworth (2006). These were as follows.

1. **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 ($\frac{\overline{\beta}_{y-3,y-2,y-1}}{\overline{\beta}_{89-04}}$), where $\overline{\beta}_{\{y\}}$ indicates the average value of $\beta$ 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.

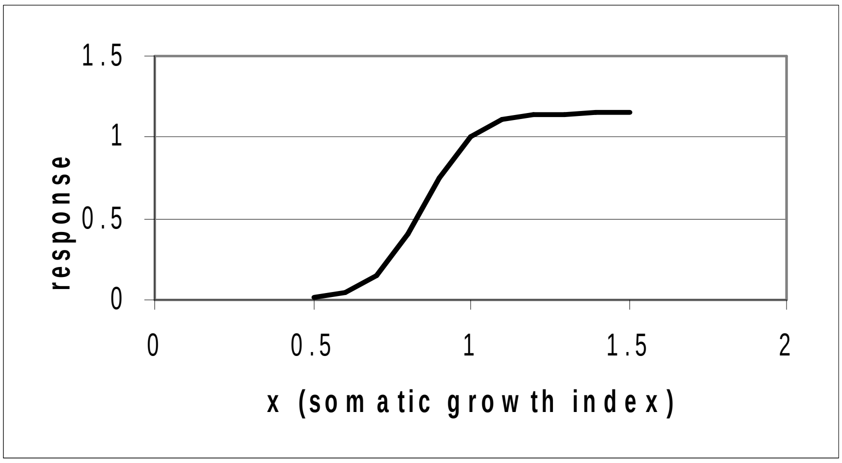
2. **Alternate response to somatic growth changes**

If $x = \frac{\overline{\beta}_{y-3,y-2,y-1}}{\overline{\beta}_{89-04}}$, then the response to the somatic growth rate index in the OMP was initially given by $x^{\lambda}$ (see Eqn (1)), with $\lambda$ 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:

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

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:




### 3. Decrease weight of FIMS data in OMP

The weights given to the TRAP:HOOP:FIMS data in the last factor of Eqn (1) are 0.4:0.4:0.2.

### 4. Geometric averages

The OMP has been modified so that when taking averages of the input data in the OMP calculations, 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.

### 5. 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 ($\sigma$ 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 $\varepsilon$ such that
if $\varepsilon > 1.8$ $\quad \varepsilon = 1.8$
if $\varepsilon < -2.0$ $\quad \varepsilon = -2.0$

**Summary of order of TAC calculations**

1. OMP generates the global (all super-areas combined) commercial+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 2% of commercial TAC from A8 to A34.

# Appendix 2: Empirical-based OMPs

For this exercise, the OMPs were tested assuming future somatic growth remain low for all years in the future.

**OMP A**
Simple CC = 2200 MT where the catches are fixed for each super-area as follows:
A1-2 = 30 MT
A3-4 = 230 MT
A5-6 = 40 MT
A7 = 590 MT
A8 = 1310 MT

**OMP B**
This is the “complicated” OMP where a population model is fitted to the trap CPUE, hoop CPUE and FIMS data etc.

**OMP C**
A more simple empirical OMP as follows:

$$TAC_{y+1} = 0.5TAC_y + 0.5\left[\alpha\left\{\left(\frac{cpue\,trap_{y-1,y-3}}{cpue\,trap_{93-95}}\right)^{0.4}\left(\frac{cpue\,hoop_{y-1,y-3}}{cpue\,hoop_{93-95}}\right)^{0.4}\left(\frac{FIMS_{y-1,y-3}}{FIMS_{92,95}}\right)^{0.2}\right\}^{0.5}\right]$$

**OMP D**
A simple OMP based upon trap CPUE slope.

$$TAC_{y+1} = 0.5TAC_y + 0.5\left[TAC_y\{1 + t + \lambda\, slope\}\right]$$

where *slope* is obtained from a log-linear regression of the (combined over all areas) trap CPUE data from 2000 to $y$-1.

**OMP E**
Identical to OMP D, except the slope is calculated using the (combined over all areas) FIMS data.

**OMP F**
Here the OMP is based on the inverse weighted slopes from trap CPUE, hoop CPUE and FIMS cpue as follows:

1. For each year of the OMP, regress the trap cpue, hoop cpue and FIMS data from 2000 to $y$-1 against year.
2. Calculate an inverse weighted slope.
3. Calculate slope* using Fig. 1 below.
4. Finally calculate the TAC as follows:

$$TAC_{y+1} = 0.5TAC_y + 0.5\left[TAC_y\{1 + t + \lambda\, slope^*\}\right]$$

The tuning parameters (to obtain an average TAC=2200 MT) are:

$\lambda = 1.0$

$a = b = 0.1$

$t = -0.04$

**For all results presented below, the OMPs have been tuned so that the average commercial TAC over the 10 year projection period is 2200 MT.**

Fig. 1: Calculation of slope* from slope for OMP F

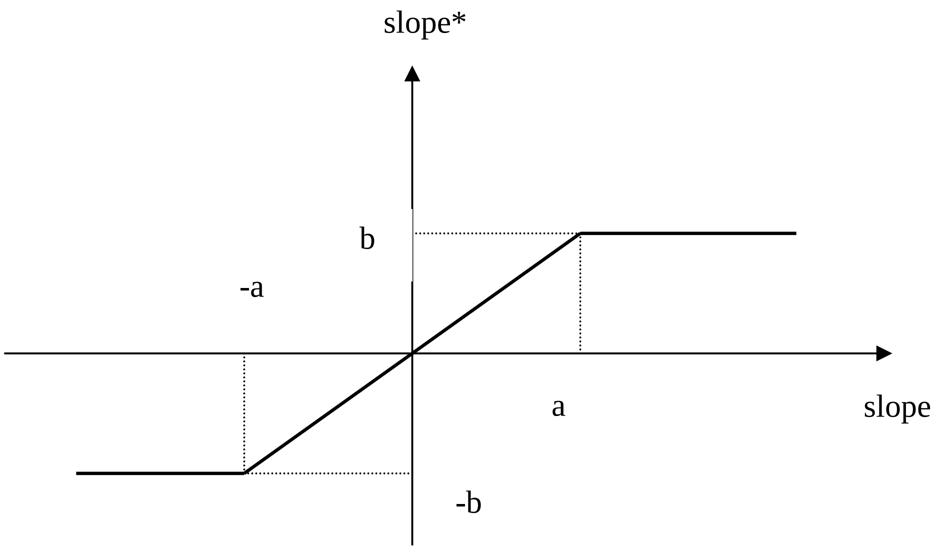


Table A2.1: $B^T$(16/06) with 90% PIs. For all results, the future somatic growth rate is low for all scenarios, with only recruitment varying.

| | **A** | **B** | **C** | **D** | **E** | **F** |
|---|---|---|---|---|---|---|
| | **CC = 2200 MT** | **COMPLICATED OMP** $\alpha$ **=3900** | **SIMPLE OMP** $\alpha$ **=2550** | **Simple Trap** $\lambda = 1$; $t$ = 0.014 | **Simple FIMS** $\lambda = 1$; $t$ = -0.038 | **Simple COMBINED** $\lambda = 1$; $t$ = -0.04 |
| **A1-2** | 0.77 [0.48; 1.30] | 0.79 [0.51; 1.32] | 0.79 [0.51; 1.32] | 0.79 [0.51; 1.33] | 0.79 [0.51; 1.33] | 0.79 [0.51; 1.33] |
| **A3-4** | 0.87 [0.46; 1.92] | 0.83 [0.49; 1.91] | 0.84 [0.44; 1.90] | 0.85 [0.43; 1.91] | 0.86 [0.46; 1.90] | 0.85 [0.43; 1.90] |
| **A5-6** | 1.50 [0.51; 8.43] | 1.52 [0.56; 8.47] | 1.53 [0.55; 8.48] | 1.53 [0.55; 8.48] | 1.54 [0.56; 8.48] | 1.42 [0.52; 7.72] |
| **A7** | 1.22 [0.35; 3.25] | 1.23 [0.50; 3.16] | 1.23 [0.49; 3.26] | 1.22 [0.48; 3.21] | 1.27 [0.45; 3.22] | 1.24 [0.46; 3.25] |
| **A8** | 0.63 [0.16; 1.37] | 0.69 [0.34; 1.40] | 0.71 [0.28; 1.46] | 0.70 [0.21; 1.46] | 0.72 [0.27; 1.46] | 0.71 [0.26; 1.44] |
| **T** | 0.95 [0.43; 2.07] | 0.97 [0.60; 2.07] | 1.00 [0.54; 2.11] | 1.00 [0.50; 2.13] | 0.99 [0.53; 2.09] | 0.99 [0.52; 2.08] |

Figure A2.1: *B*(16/06) medians with 90% PIs for 4 OMPS (CC, B = complicated, E = FIMS slope and F = combined slopes).