OMP 2007 re-cast to be used for setting TACs for the West Coast rock lobster fishery for the 2008+ seasons

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Summary

This document first gives the reasons why the OMP agreed for West Coast rock lobster in 2007 (OMP-2007) was "re-cast" the following year, listing the modifications then introduced. It then provides details of the three main components of "OMP-2007 re-cast": 1) how data are combined across the five super-areas (Area 1-2, Area 3-4, Area 5-6, Area 7 and Area 8) for input into the OMP; 2) the OMP formulae which provide the global TAC recommendation; and 3) the manner in which the global TAC is split amongst super-areas and resource user-groups.

Introduction

OMP-2007 was the OMP variant selected for setting TACs for the 2007+ seasons[1] (Johnston and Butterworth 2007). OMP-2007 is estimated to lead to a median average commercial TAC over the 10-year period (2006-2015) of 2336 MT and a biomass (above 75mm carapace length) recovery of male lobsters of 20.6% by 2016, i.e. $B^{m,75}_{2016} / B^{m,75}_{2006}$ =1.206.

"OMP-2007 re-cast"

In early 2008 it was decided by the Rock Lobster Scientific Working Group to re-cast OMP-2007 before applying it to produce the TAC recommendation for the 2008 season. This re-casting was required to accommodate the Group's recommendation that nearshore rights holder allocations vary in similar fashion to recreational allocations. For the reason that this also required OMP re-tuning, the opportunity was taken to update two other aspects, i.e. three adjustments have been made in all to OMP-2007:

i) During the 2006 season the full commercial TAC was not caught – "OMP-2007 re-cast" takes this into account by updating the operating models of the resource (used for testing the OMP) with the actual catches made, and not the TACs. The catch values for each super-area used are as follows (the TAC value is in brackets):

Area 1-2:	8.4 MT	(30 MT)

[1] The convention used in this document is that the "2007 season" refers to the season commencing in 2007 and concluding in 2008, i.e. to 2007/8.

Area 3-4:	1.3 MT	(100 MT)
Area 5-6:	0 MT	(40.25 MT)
Area 7:	526.8 MT	(821.75 MT)
Area 8:	1670.6 MT	(1565 MT)
Total:	2207.1 MT	(2557 MT)

The effective overall under-catch from the 2006 season was thus 2557 - 2207 = 350 MT.

These 2006 catches also take into account the amount that was caught in 2006 which was actually part of the "over-catch" allowed from 2005. Appendix 1 provides details of these calculations.

Note also that the 2007 TAC values are used in "OMP-2007 re-cast" (not the catches, as these are unknown at the time of the re-cast OMP tuning).

ii) During the 2007 season an additional catch in the form of an interim relief allocation was allowed by the Minister. The estimated additional amount to be attributed to this interim relief catch is 175.06 MT (Keulder and van Zyl 2008). This amount (175.06 MT) is now taken into account in the re-cast OMP – in updating both the historic catches considered in operating models as well as the historic catches used in the OMP population model. The breakdown of the interim relief tonnage is as follows:

Area 1-2:	9.1 MT
Area 3-4:	27.3 MT
Area 5-6:	25.3 MT
Area 7:	0 MT
Area 8:	44.5 MT

iii) "OMP-2007 re-cast" also makes a change to the way Nearshore Rights Holders (NRH) TACs are calculated. OMP-2007 fixed these at the following values:

Super-Area	**Nearshore 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

"OMP-2007 re-cast" now calculates the NRH TACs in a manner similar to that for recreational takes – see below (pg 10) for further details. The reason, as stated in previous recommendations made by the Working Group, is that it is not scientifically defensible to maintain constant catch allocations in circumstances where resource abundance can drop as a result of recruitment fluctuations, and responsible management must allow for catch reductions in such circumstances (note also that for two of the five super-areas, the complete allocation is to NRHs only).

Note further that "OMP-2007 re-cast" also makes a slight modification with respect to somatic growth rate inputs into the OMP – see Appendix 2 for details.

"OMP-2007 re-cast" (as did OMP-2007) involves three main components:

1. The combination of data across super-areas for input into the OMP.
2. The OMP formulae to provide a global TAC recommendation.
3. The split of global TAC amongst super-areas and resource user groups.

The sections that follow detail each of these in turn and apply to "OMP-2007 re-cast".

1. The combination of data across super-areas

The OMP uses input data from all five super-areas where available.

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 season in the future. The last three of these are combined across super-areas as follows:

STEP 1: For each super-area for which data are assumed to be available in the future, there will be for any season *Y* (here trap CPUE is used as an example):

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

STEP 2: Evaluate the geometric means of the CPUEs (and FIMS) for the super-area concerned (here we use A1-2 as an example) over the year period 1993…*Y*-1 for traps and hoops, and for the period 1992…*Y*-1 for FIMS data.

STEP 3: Re-normalise the hoop and trap CPUEs series as follows (e.g. for traps in Area A1-2):

$$CPUE_Y^{trap,A1-2} \Rightarrow X_Y^{trap,A1-2} = \frac{CPUE_Y^{trap,A1-2}}{Geometric\ mean\ (CPUE_y^{trap,A1-2}:\ y = 1993...(Y-1))} \qquad (1)$$

and the FIMS series

$$CPUE_Y^{FIMS,A1-2} \Rightarrow X_Y^{FIMS,A1-2} = \frac{CPUE_Y^{FIMS,A1-2}}{Geometric\ mean\ (CPUE_y^{FIMS,A1-2}:\ y = 1992...(Y-1))} \qquad (2)$$

STEP 5: Calculate a combined CPUE (and FIMS) index as follows:

$$X_Y^{trap,TOTAL} = w_{A1-2}^{trap} X_Y^{trap,A1-2} + w_{A3-4}^{trap} X_Y^{trap,A3-4} + ... + w_{A8}^{trap} X_Y^{trap,A8} \qquad (3)$$

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

The weights are calculated in the following manner. For example, for trap and hoop CPUE, obtain $\overline{B}^{75}$, the average (male plus female) selectivity-weighted biomass above 75mm carapace length over the 2000-2004 period for each super-area (the source of these biomass estimates is specified below):

$$\overline{B}_{A1-2}^{75}, \overline{B}_{A3-4}^{75}, \overline{B}_{A5-6}^{75}, \overline{B}_{A7}^{75}, \overline{B}_{A8}^{75};$$

then:

$$\overline{B}_{TOTAL}^{75} = \sum_{A=1..8} \overline{B}_A^{75} \text{ and} \qquad (4)$$

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

For FIMS, as above, but $\overline{B}^{60}$ is used instead of $\overline{B}^{75}$ (again, the biomass weighted by the appropriate selectivity is used from the source specified below).

Since there will be a lack of certain data types for some super-areas, 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.

Note: If there is a data value missing for a particular super-area in season *y*, then the average of the values for the $y-1$ and $y+1$ seasons values is to be used in its place.

Combined somatic growth index (β_y):

What is needed is an index, e.g. 70mm male annual somatic growth, as used in the assessment for each separate super-area (Johnston and Butterworth 2006).

The procedure is to use similar weighting factors, e.g. $w_{A1-2}^{SG} = \frac{\overline{B}_{A1-2}^{m,70}}{\overline{B}_{TOTAL}^{m,70}}$, 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 $\beta_y = w_{A1-2}^{SG}\beta_y^{A1-2} + w_{A3-4}^{SG}\beta_y^{A3-4} + w_{A5-6}^{SG}\beta_y^{A5-6} + w_{A7}^{SG}\beta_y^{A7} + w_{A8}^{SG}\beta_y^{A8}$ (5)

where:

β_y is the super-areas combined annual somatic growth in mm of a 70mm male lobster in season *y*.

The assessments referenced above are taken to be the MARAM/OLRAC averaged RC1-like assessments conducted in 2006 (Johnston and Butterworth 2006), so that the biomasses above are all available and hence also the weighting factors. 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 hence such data are omitted from the OMP.]

	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

Appendix 2 reports the super-area somatic growth input data for each super-area and provides the details of the associated data analyses.

The somatic growth data provided in Appendix 2 led to the single index series reported as "new series" in Table 1. In Table 1 the single index series used for the period 1992-2005 in the simulations used in developing OMP-2007 (Johnston and Butterworth 2007) is also provided ("old series"). In order to retain the same average somatic growth rate over the 1992-2005 period under simulated conditions and using the new data series, the "new series" is renormalized so that its 1992-2005 average is identical to the "old series" average. Thus the "renormalized new series" is the final single index somatic growth rate series used as input into "OMP-2007 re-cast". Future somatic growth rate indices provided by the OLRAC (2005) moult probability model (see Appendix 2) will be renormalised by this same factor.

Table 2 reports the resultant single-index input data series for all four data series for the calculation of the 2008 TAC which were used in conjunction with "OMP-2007 re-cast".

Appendix 3 reports the super-area trap CPUE input data for each super-area and provides the details of the associated data analyses.

Appendix 4 reports the super-area hoop CPUE input data for each super-area and provides the details of the associated data analyses.

Appendix 5 reports the super-area FIMS input data for each super-area and provides the details of the associated data analyses.

2. OMP TAC setting rule

The following basic TAC algorithm is used to calculate the global (commercial + recreational all super-areas) TAC recommendation (TAC_y^G) for season *y*, but subject to modifications i) – iii) detailed at the end of this section:

$$TAC_y^G = w_y TAC_{y-1}^G + (1-w_y)\alpha\left(\frac{\beta_{y-5,y-4,y-3,y-2,y-1}}{\overline{\beta}_{89-04}}\right)^{\lambda}\left(\frac{\hat{B}_y}{\hat{B}_{1992}}\right) \quad \text{x}$$

$$\left[f_1\left(\frac{CPUE_{y-1,y-2,y-3}^{trap}}{CPUE_{93,94,95}^{trap}}\right) + f_2\left(\frac{CPUE_{y-1,y-2,y-3}^{hoop}}{CPUE_{93,94,95}^{hoop}}\right) + (1-f_1-f_2)\left(\frac{FIMS_{y-3,y-2,y-1}}{FIMS_{92,93,94,95}}\right)\right]^p \qquad (6)$$

Where:

w_y = 0.50 for all seasons;
p = 0.5;
f_1 = 0.40;
f_2 = 0.40; and
α is the primary tuning parameter, which for "OMP-2007 re-cast" is 4560.

[Note that this primary tuning parameter value ensures that the anticipated median male (above 75mm carapace length) biomass recovery over the 10-year period considered is 20.6%, ie. that B_{2016}^m / B_{2006}^m =1.206.]

Note that β refers to the somatic growth rate of a 70mm male lobster (combined over all super-areas in the manner specified in the previous section), and that $\overline{\beta}_{89-04}$ refers to the geometric mean β over the 1989-2004 period of historic growth (and has a value of 3.504mm). Note also that it is the multiplicative factor in equation (6) related to the β parameters that is changed under modification ii) below.

The choice of control parameter values f_1 and f_2 for the final term means a TRAP:HOOP:FIMS abundance index data relative weighting of 0.4:0.4:0.2.

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

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

$$B_{Y+1}^{p} = B_{Y}^{p} + G_{Y} - (C_{Y} + P_{Y}) \qquad (7)$$

where:

B_Y^p = population model biomass in season *Y;*
G_Y = annual "growth" of resource in season *Y,*
C_Y = annual commercial + recreational catch in season *Y*[2]; and
P_Y = annual estimate of poaching for season *Y*.

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

Past catch data are given in Appendix 6.

The annual somatic growth parameter β_Y is the moult-probability model (OLRAC 2005, Appendix 2) estimated somatic growth of a male rock lobster of 70mm carapace length (renormalized as detailed in the preceding text). For any season *y* for which a TAC is required, β_Y is known for all preceding seasons.

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

$$G_Y = a(\beta_Y + b) \qquad (8)$$

The value of *b* is set externally by regressing against β the equilibrium sustainable yield corresponding to the estimate of the biomass (male and female above 75mm carapace length) in 2005 (for the case where all the super-areas are considered together) for different values of β (this relationship is near linear). The intercept of this regression with the horizontal axis (for β), averaged over three area-aggregated assessments RC1, ALTL and ALTH (Johnston and Butterworth 2006), yields a value of b = -2.5636 mm for use in equation (8). Parameter *a* is estimated in the fitting of the population model of equation (6) to the data as described below.

Each season *y* (from *y* = 2007), as new data become available, the population model (see equation 6) is fitted by minimising the following negative log-likelihood:

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[2] Note that an extra 175.06 MT is added for the 2007 season to take into account the interim relief tonnage taken. Interim relief estimates for 2007+ years will also be taken into account in this manner.

$$-\ln L = \sum_{Y=1993}^{y-1}\left\{\ln\sigma_{CPUE^{trap}} + \frac{1}{2\sigma^2_{CPUE^{trap}}}\left(\ln CPUE_Y^{trap} - \ln q_{CPUE^{trap}} - \ln B_Y^P\right)^2\right\}$$
$$+ \sum_{Y=1993}^{y-1}\left\{\ln\sigma_{CPUE^{hoop}} + \frac{1}{2\sigma^2_{CPUE^{hoop}}}\left(\ln CPUE_Y^{hoop} - \ln q_{CPUE^{hoop}} - \ln B_Y^P\right)^2\right\} \quad (9)$$
$$+ \sum_{Y=1992}^{y-1}\left\{\ln\sigma_{FIMS} + \frac{1}{2\sigma^2_{FIMS}}\left(\ln FIMS_Y - \ln q_{FIMS} - \ln B_Y^P\right)^2\right\}$$

where:

$CPUE_Y^{trap}$ is the trap CPUE for season Y;

$CPUE_Y^{hoop}$ is the hoop CPUE for season Y;

$FIMS_Y$ is the FIMS CPUE for season Y;

$q_{CPUE^{trap}}$ is the trap catchability coefficient;

$q_{CPUE^{hoop}}$ is the hoop catchability coefficient;

q_{FIMS} is the FIMS catchability coefficient;

$$\ln q_{CPUE^{trap}} = \frac{\sum_{Y=1993}^{y-1}\left(\ln CPUE_Y^{trap} - \ln B_Y^P\right)}{n_{CPUE^{trap}}}; \quad (10)$$

$$\ln q_{CPUE^{thoop}} = \frac{\sum_{Y=1993}^{y-1}\left(\ln CPUE_Y^{hoop} - \ln B_Y^P\right)}{n_{CPUE^{hoop}}}; \quad (11)$$

$$\ln q_{FIMS} = \frac{\sum_{Y=1992}^{y-1}\left(\ln FIMS_Y - \ln B_Y^P\right)}{n_{FIMS}}; \quad (12)$$

$$\sigma_{CPUE^{trap}} = \sqrt{\frac{\sum_{Y=1993}^{y-1}\left(\ln CPUE_Y^{trap} - \ln q_{CPUE^{trap}} - \ln B_Y^P\right)^2}{n_{CPUE^{trap}}}}; \quad (13)$$

$$\sigma_{CPUE^{hoop}} = \sqrt{\frac{\sum_{Y=1993}^{y-1}\left(\ln CPUE_Y^{hoop} - \ln q_{CPUE^{hoop}} - \ln B_Y^P\right)^2}{n_{CPUE^{hoop}}}}; \quad (14)$$

$$\sigma_{FIMS} = \sqrt{\frac{\sum_{Y=1992}^{y-1}\left(\ln FIMS_Y - \ln q_{FIMS} - \ln B_Y^P\right)^2}{n_{FIMS}}}; \text{ and} \quad (15)$$

n = number of data points in the series referenced.

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

The following penalty function is added to the negative log-likelihood function for the "a" parameter of the G_Y relationship (equation 8) used to stabilise the estimation:

$$P = \frac{(a-3000)^2}{2\sigma_a^2} \quad (16)$$

where $\sigma_a = 1000$.

Thus, equation (9) becomes:

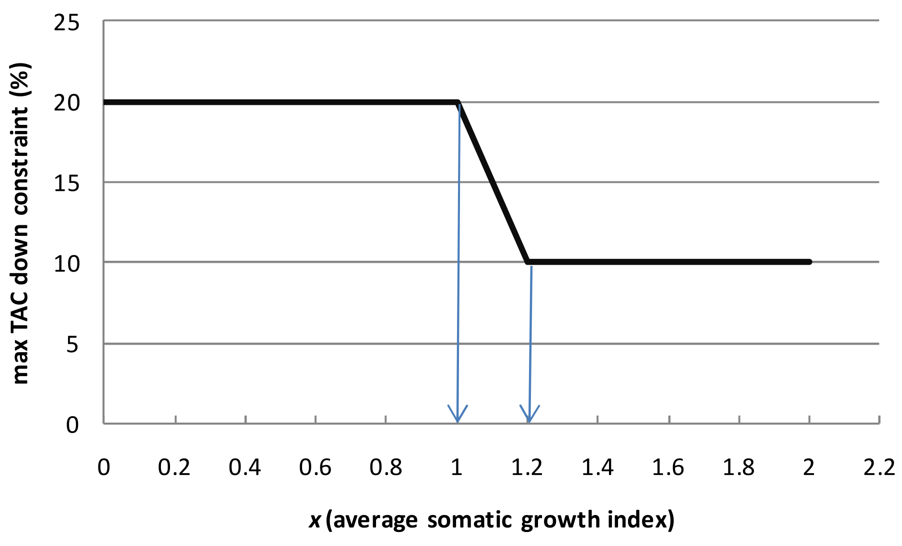
$$
\begin{aligned}
-\ln L = & \sum_{Y=1993}^{y-1}\left\{\ln\sigma_{CPUE^{trap}} + \frac{1}{2\sigma^2_{CPUE^{trap}}}\left(\ln CPUE_y^{trap} - \ln q_{CPUE^{trap}} - \ln B_Y^P\right)^2\right\} \\
& + \sum_{Y=1993}^{y-1}\left\{\ln\sigma_{CPUE^{hoop}} + \frac{1}{2\sigma^2_{CPUE^{hoop}}}\left(\ln CPUE_y^{hoop} - \ln q_{CPUE^{hoop}} - \ln B_Y^P\right)^2\right\} \qquad (17) \\
& + \sum_{Y=1992}^{y-1}\left\{\ln\sigma_{FIMS} + \frac{1}{2\sigma^2_{FIMS}}\left(\ln FIMS_y - \ln q_{FIMS} - \ln B_Y^P\right)^2\right\} + P
\end{aligned}
$$

Note that the input data used are provided to three decimal places.

A number of further modifications are made to the basic TAC algorithm of equation (1). 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 inter-annual downward constraint

A maximum TAC downward inter-annual constraint of 10% is assumed for the first two seasons (2007 and 2008). From 2009 onwards, this constraint is modified according to the value of the somatic growth rate index ($x = \frac{\bar{\beta}_{y-5,y-4,y-3,y-2,y-1}}{\bar{\beta}_{89-04}}$), where $\bar{\beta}_{\{y\}}$ indicates the geometric mean of the somatic growth index β over the seasons in $\{y\}$, as follows:



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

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

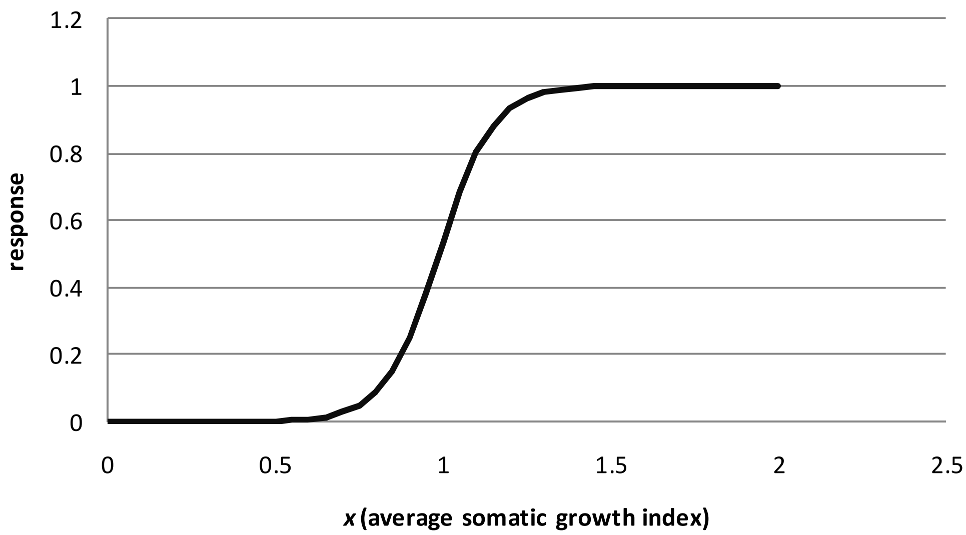
ii) Response to somatic growth changes

If $x = \frac{\overline{\beta}_{y-5,y-4,y-3,y-2,y-1}}{\overline{\beta}^{historic}_{89-04}}$ (where $\overline{\beta}^{historic}_{89-04} = 3.504\ \text{mm}$), then the response to the annual average somatic growth rate index in the basic TAC algorithm (equation (5)) is given by x^{λ}, with λ set at 1 so that this term varies linearly with recent somatic growth rate.

The final OMP 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:

$$x^{\lambda} \rightarrow \frac{1+P_1}{1+P_1 e^{-(x-P_2)/P_3}} \qquad (18)$$

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



iii) **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 super-areas into a single index for input into the OMP) is imposed. The reason relates to the fact that for some simulations used in the OMP testing process, 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 occurred. To avoid the associated high output variance which could result, a cap was imposed in the simulations, and so is similarly imposed on real data for any input index value (from any of the 5 super-areas). Thus any value which is greater then 2.5 times the arithmetic average of the previous 5 years' values is capped at that average value multiplied by 2.5.

3. The split of the global (combined) TAC generated from the OMP split amongst the super-areas

The final OMP TAC setting rule produces a recommended global TAC each season - TAC_y^G .

For the recreational take component, the following algorithm is applied:

$C_y^{rec} = C_{y-1}^{rec}$ initially (i.e. for the 2007 season)

$$\begin{aligned} &\text{If } C_y^{rec}/TAC_y^G > 0.12 \quad \text{then} \quad C_y^{rec} = 0.10\ TAC_y^G \\ &\text{If } C_y^{rec}/TAC_y^G < 0.08 \quad \text{then} \quad C_y^{rec} = 0.10\ TAC_y^G \end{aligned} \qquad (19)$$

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

where C_y^{rec} is the overall recreational take for season *y*, and TAC_y^G is the "global" (commercial plus recreational) TAC for season *y* as output by the OMP. (Note that recreational take limits are not imposed directly. Rather if a change in this take is indicated, recommendations for changes to the extent of the recreational season will be made which are chosen with the intent of achieving the change in take sought.)

Note that the following proportional breakdown of the overall recreational take (C_y^{rec}) by super-area is assumed for the purposes of OMP trials; these proportions are taken in the trials to remain unchanged over time:

Area 1-2	= 2%	
Area 3-4	= 12.5%	
Area 5-6	= 12.5%	(20)
Area 7	= 4%	
Area 8	= 69%	

The remaining (commercial) TAC ($TAC_y^{comm} = TAC_y^G - C_y^{rec}$) (adjusted if necessary at this stage to conform to inter-annual TAC change constraints) must then be split into super-area allocations. First the nearshore allocations are calculated, and then subtracted as indicated below.

The total nearshore allocation may vary up and down over time in a similar manner to the recreational take. Thus, first the total nearshore TAC each season, NSQ_y, is calculated as follows:

$NSQ_y = NSQ_{y-1}$ initially (i.e. for the 2007 season)

$$\begin{aligned} &\text{If } NSQ_y/TAC_y^G > 0.24 \quad \text{then} \quad NSQ_y = 0.195\ TAC_y^G \\ &\text{If } NSQ_y/TAC_y^G < 0.16 \quad \text{then} \quad NSQ_y = 0.195\ TAC_y^G \end{aligned} \qquad (21)$$

If $NSQ_y > 800$ MT then $NSQ_y = 800$ MT.

The proportional inter-super-area split of the NSQ_y remains the same as for 2006, i.e.:

$$\begin{aligned}
&\text{Area 1-2} \quad NSQ_y^{A1-2} = 5.36\% \text{ of } NSQ_y \\
&\text{Area 3-4} \quad NSQ_y^{A3-4} = 16.07\% \text{ of } NSQ_y \\
&\text{Area 5-6} \quad NSQ_y^{A5-6} = 7.14\% \text{ of } NSQ_y \\
&\text{Area 7} \quad NSQ_y^{A7} = 0\% \text{ of } NSQ_y \\
&\text{Area 8} \quad NSQ_y^{A8} = 71.43\% \text{ of } NSQ_y
\end{aligned} \tag{22}$$

Finally the TAC allocation to offshore rights holders in each super-area A, $TAC_y^{off} = TAC_y^{comm} - NSQ_y$, is divided between super-areas A3-4, A7 and A8 as follows:

STEP 1: For each of these super-areas there are 1-3 abundance index time series. For each index, linearly regress *ln*(index) *vs* season for the last seven seasons 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:

$$slope^A = \frac{\left(\frac{slope^A_{trap}}{\sigma^2_{slope^A_{trap}}} + \frac{slope^A_{hoop}}{\sigma^2_{slope^A_{hoop}}} + \frac{slope^A_{FIMS}}{\sigma^2_{slope^A_{FIMS}}}\right)}{\frac{1}{\sigma^2_{slope^A_{trap}}} + \frac{1}{\sigma^2_{slope^A_{hoop}}} + \frac{1}{\sigma^2_{slope^A_{FIMS}}}}$$ (assuming three series),

(23)

where:

$\sigma^2_{slope^A} = \frac{1}{n-2}(slope^A)^2 \frac{1-r^2}{r^2}$ from each regression, where *r* is the correlation coefficient and *n* = 7 given that seven seasons of data are used.

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

STEP 4: Take the previous season's offshore commercial allocation for the super-area and multiply it by (1+$slope^A$) for that super-area, giving a new set of commercial allocations by super-area, which will not necessarily total to the new overall offshore commercial TAC (TAC_y^{off}) for the super-areas concerned. If the allocations do not total to that offshore commercial TAC, simply scale them all by the same proportion so that they do total to match that offshore commercial TAC.

STEP 5: Transfer of 5% of the offshore commercial TAC (TAC_y^{off}) from A8 to A3-4 and A7 in the ratio 1:4.

The commercial rights holders TAC allocations by super-area are then simply calculated as:

$$TAC_y^{comm,A} = TAC_y^{off,A} + NSQ_y^A . \qquad (24)$$

Summary of the order of the TAC calculations

1. The OMP generates the global (all super-areas combined) commercial (offshore+nearshore rights holders)+recreational TAC = TAC_y^G recommendation.
2. Check for inter-annual TAC constraint violations (at a global level) and adjust TAC_y^G if necessary.
3. Remove the total recreational take component (which would then be split into super-areas as per the specified proportions for subsequent computations in any simulation testing):
   $$TAC_y^{comm} = TAC_y^G - C_y^{rec} .$$
4. Re-check that the remaining commercial (offshore+nearshore rights holders) TAC_y^{comm} does not violate inter-annual TAC constraints; if it does, adjust it to the bound concerned.
5. Calculate the total nearshore TAC, NSQ_y .
6. Split the total nearshore TAC component into super-areas according to fixed proportions – note no nearshore TAC allocation for super-area A7. This gives: $NSQ_y^{A1-2}, NSQ_y^{A3-4}, NSQ_y^{A5-6}, NSQ_y^{A8}$. Note NSQ_y^{A7}=0.
7. Remove the total nearshore TAC component from the total commercial TAC to give the amount to be split into offshore TAC for super-areas A3-4, A7 and A8 (note no offshore TAC allocations for A1-2 and A5-6), i.e.:
   $$TAC_y^{off} = TAC_y^{comm} - NSQ_y .$$
8. Split the offshore TAC into A3-4, A7 and A8 (using the slopes method above– this gives initial $TAC_y^{off,A3-4}, TAC_y^{off,A7}, TAC_y^{off,A8}$). Note that $TAC_y^{off,A1-2}$ and $TAC_y^{off,A5-6}$ are both equal to zero.
9. Transfer 5% of offshore TAC from A8 into A3-4 (20%) and A7 (80%):
   $$TAC_y^{off,A3-4} = TAC_y^{off,A3-4} + (0.2)(0.05)TAC_y^{off,A8}$$
   $$TAC_y^{off,A7} = TAC_y^{off,A7} + (0.8)(0.05)TAC_y^{off,A8}$$
   $$TAC_y^{off,A8} = 0.95TAC_y^{off,A8} .$$
10. The final commercial TAC allocations are then:
   $$TAC_y^{comm,A1-2} = TAC_y^{off,A1-2} + NSQ_y^{A1-2}$$
   $$TAC_y^{comm,A3-4} = TAC_y^{off,A3-4} + NSQ_y^{A3-4}$$
   $$TAC_y^{comm,A5-6} = TAC_y^{off,A5-6} + NSQ_y^{A5-6}$$
   $$TAC_y^{comm,A7} = TAC_y^{off,A7} + NSQ_y^{A7}$$
   $$TAC_y^{comm,A8} = TAC_y^{off,A8} + NSQ_y^{A8}$$

Notes: It is hypothetically possible (but very unlikely) that steps 3 or 7 above could result in negative allocations. Should such extreme circumstances arise, they would be grounds for and dealt with under the Exceptional Circumstances provisions specified in the overall protocol for OMPs (Butterworth and Johnston 2010).

Further the OMP relies on the overall mechanism for adjusting nearshore allocations as being sufficient to counter negative resource trends in super-areas A1-2 and A5-6, for which only nearshore allocations are made, rather than to react directly to abundance index trends for these super-areas only. This is to avoid a situation where quotas for individual nearshore rights holders would differ between super-areas. However, this situation will be kept under review in terms of the routine assessments conducted under the agreed overall protocol for OMPs, and dealt with under Exceptional Circumstances provisions should sufficiently adverse resource trends in either of these two super-areas become evident.

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Table 1: The annual somatic growth data (in mm for a 70m carapace length male lobster) used in simulations to develop OMP-2007 (“old series”), the updated “new series” for somatic growth (Appendix 2) and the final “renormalized new series” data used as input to calculate the TAC recommendations for 2008.

Season	Old series	New series	Renormalised new series
1992	2.976	2.954	2.884
1993	3.527	3.539	3.455
1994	3.648	3.606	3.521
1995	4.008	3.995	3.901
1996	4.936	5.001	4.883
1997	3.637	3.597	3.512
1998	3.135	3.031	2.959
1999	3.227	3.228	3.152
2000	4.484	4.425	4.321
2001	3.741	3.774	3.685
2002	3.852	3.921	3.828
2003	2.686	2.872	2.804
2004	3.075	3.904	3.812
2005	2.777	3.068	2.996
2006		2.886	2.818
2007		2.181	2.130
ave 1992-2005	3.551	3.637	3.551

Table 2: The final single-index abundance input data into "OMP-2007 re-cast" to provide the 2008 TAC recommendations.

Season	Somatic growth	Trap CPUE	Hoop CPUE	FIMS
1992	2.884			1.953
1993	3.455	0.725	0.942	1.300
1994	3.521	0.584	0.797	0.940
1995	3.901	0.801	1.078	1.602
1996	4.883	0.979	1.160	2.541
1997	3.512	1.074	1.129	0.771
1998	2.959	1.212	1.231	1.687
1999	3.152	1.133	1.167	1.336
2000	4.321	1.255	1.097	1.061
2001	3.685	1.732	1.754	1.527
2002	3.828	1.638	0.987	1.237
2003	2.804	1.289	0.999	1.092
2004	3.812	1.122	0.833	1.007
2005	2.996	0.838	0.944	1.395
2006	2.818	0.987	0.808	0.799
2007	2.130	0.691	1.032	1.026

Appendix 1: Details of TACs awarded and catches made in the 2005 and 2006 seasons

Table A1.1: TAC and actual catches (in MT) for 2005 season.

	A	B	A-B
	2005 TAC	**Actual Catch**	**Under-catch 2005**
Area1-2	30.0	16.0	14.0
Area 3-4	108.0	89.0	19.0
Area 5-6	40.5	11.0	29.5
Area 7	969.3	558.0	411.3
Area 8+	1727.5	1323.0	404.5
Total	**2875.3**	**1997.0**	**878.3**

Table A1.2: Details of the 2006 season TACs and catch allocations (in MT).

	A	B	A+B	C	C-B	(A+B)-C
	2006 TAC from OMP	**2005 roll-over**	**total 2006 "TAC"**	**Actual 2006 Catch taken**	**Catch attributed to 2006**	**Under-catch 2006**
Area1-2	30.0	14.0	44.0	22.4	8.4	21.6
Area 3-4	100.0	19.0	119.0	20.3	1.3	98.7
Area 5-6	40.25	29.5	69.75	16.3	0.0	53.45
Area 7	821.75	411.3	1233.05	938.1	526.8	294.95
Area 8+	1565.0	404.5	1969.5	2075.1	1670.6	-105.6
Total	**2557**	**878.3**	**3435.3**	**3072.2**	**2207.1**	**363.1**

Appendix 2: Methodology for estimating annual male somatic growth rate for input into the spatially disaggregated assessment and OMP-2007 re-cast for West Coast rock lobsters

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1. Introduction

The moult-probability model, since its introduction by OLRAC to the Rock Lobster Working Group in 2002, has undergone several stages of further development. The purpose of this document is to present a comprehensive description of the methodology in its current form, which is used to produce standardized, area-disaggregated somatic growth series for input into the stock assessment and the OMP for West Coast rock lobsters.

2. Area classification

Four levels of area sub-division are used for the growth analysis:

- 5 super-areas, for each of which a standardized growth rate time series is produced for input into the assessment and the OMP;
- 11 macro-areas, for each of which a separate moult window distribution is assumed;
- 14 areas – these are the area definitions used for the assessment. They do not play any explicit part in the growth analysis, but are included here for reference; and
- 30 sub-areas, for each of which a different area factor is assumed in the growth rate model.

The classification is shown in Table A2.1.

3. Data

Data used are the mark-recapture data provided by MCM, including the following information fields:

- Sex.
- Date of original capture.

- Date of release.
- Date of recapture.
- Sub-area of original capture.
- Sub-area of release.
- Sub-area of recapture.
- Sub-area at release.
- Sub-area at recapture.

The following records are excluded from the dataset for the growth analysis described below:

1. Female lobsters.
2. Lobsters with more than two missing or damaged appendages.
3. Lobsters recaptured in the ‘Factory’ area.
4. Lobsters captured (prior to release) in a different area to which they were released.
5. Lobsters recaptured in a different area to which they were released, provided that these areas are not defined as adjacent areas as per a working group agreement.
6. Lobsters whose total growth while at large exceeded 30 mm.
7. Lobsters whose total growth while at large was less than -3 mm.

Note that previous (GLM and GLMM) methods of growth analysis excluded, in addition, any lobster which may possibly not have moulted while at large, or which may have moulted more than once while at large. Such exclusions are not applied here. Thus as each additional season of recapture data becomes available, care should be taken that the additional dataset includes lobsters which may have been released in previous seasons.

- **Model 1** includes data from all areas *except* Port Nolloth and Hondeklip Baai (Areas 1 & 2.) The slope parameter ρ and season factors estimated are assumed to be common to all areas.
- **Model 2b** includes data from the Dassen Island area (Area 7) only. The slope parameter ρ is not estimated, but is fixed equal to the value estimated in Model 1. Season factors are estimated.
- **Model 3b** includes data from Port Nolloth and Hondeklip Baai (Areas 1 & 2) only. The slope parameter ρ and the season factors are estimated.

4. The Moult Probability Model

4.1 Definition of moult season

Moult seasons are defined as ranging from 1 April to 31 March of the subsequent season. This period is chosen so as to include the moulting window period for all areas as recorded in the biological literature, none of these periods are assumed to start before 1 April, and none of which are assumed to end before 31 March.

To this effect we consider a particular date, t (expressed as a decimal season e.g. 1998.23) to belong to moult season $y(t)$, with:

$$y(t) = \begin{cases} \text{int}(t), \text{ if } t - \text{int}(t) \leq 0.25 \\ \text{int}(t) + 1, \text{ if } t - \text{int}(t) > 0.25 \end{cases} \tag{A2.1}$$

where int(t) is the integer part of t.

The moult season of release and recapture are defined as:

$$\begin{aligned} y_i^- &= y(t_i^-) \\ y_i^+ &= y(t_i^+) \end{aligned} \tag{A2.2}$$

where:

t_i^- is the date of release for lobster i

t_i^+ is the date of recapture for lobster i.

4.2 The moult distribution and the probability of moulting while at large

The moult distribution within macro-area m and moult season y is assumed to be normal, with mean $y + \bar{x}_m$ and standard deviation δ_m, truncated at the beginning and end of the season. The parameters $\bar{x}_m$ and δ_m for each macro-area are estimated in the model fitting process.

If lobster i is released and recaptured during the same moult season, then the probability of a moult occurring while at large is:

$$pm(m_i^-) = F(t_i^+) - F(t_i^-)$$

If lobster i is released and recaptured in different seasons, then the probability of a moult occurring while at large in the season of release is:

$$pm(m_i^-) = 1 - F(t_i^-)$$

and the probability of a moult occurring while at large in the season of recapture is:

$$pm(m_i^+) = F(t_i^+)$$

where $F(t)$ is the cumulative distribution function at time t for the normal curve defined above.

For all moulting seasons between the moulting season of release and the moulting season of recapture, it is assumed that the probability that a moult occurred is 1.

For different seasons of moulting and recapture, there are four moulting possibilities for the i-th lobster, being the four combinations of (1) a moult either occurring or not occurring in the moult season of release and (2) a moult either occurring or not occurring in the moult season of recapture. The probabilities associated with these four possibilities are represented by the designation *pmoult*, and are given by the following:

Case A. Moult occurs in both seasons of release and recapture:

$$pmoult(A) = pm(m_i^-)\, pm(m_i^+) \tag{A2.3}$$

Case B. Moult occurs in neither seasons of release or recapture:

$$pmoult(B) = (1 - pm(m_i^-))(1 - pm(m_i^+)) \quad (A2.4)$$

Case C. Moult occurs in season of release but not of recapture:

$$pmoult(C) = pm(m_i^-)(1 - pm(m_i^+)) \; . \quad (A2.5)$$

Case D. Moult occurs in season of recapture but not of release:

$$pmoult(D) = (1 - pm(m_i^-))\, pm(m_i^+) \quad (A2.6)$$

It is easily verified that $pmoult(A) + pmoult(B) + pmoult(C) + pmoult(D) = 1$ (A2.7)

If a lobster was released and recaptured in the same moulting season then there are only two moult occurrence possibilities, i.e., either a moult occurred or a moult did not occur. Thus:

Case A. Moult occurs in both seasons of release and recapture:

$$pmoult(A) = pm(m_i^-) \quad (A2.8)$$

Case B. Moult occurs in neither seasons of release or recapture:

$$pmoult(B) = 1 - pm(m_i^-) \quad (A2.9)$$

Case C. Moult occurs in season of release but not of recapture:

$$pmoult(C) = 0 \quad (A2.10)$$

Case D. Moult occurs in season of recapture but not of release:

$$pmoult(D) = 0 \; . \quad (A2.11)$$

4.3 The growth model for a single moult.

$$\hat{g}_i(m) = A(a_i) + M(m) + \rho l_i^-(m) + r(a_i, m) + \mu + \varepsilon_i + \zeta_i = \hat{g}_i(m, a_i, l_i^-(m)) + \varepsilon_i(m) + \zeta_i \quad (A2.12)$$

where:

$A(a_i)$	is an area factor for sub-area a_i, ;
$M(m)$	is a moult season factor, and there is no subcript '*i*' on moulting season '*m*' because the moulting season is not unique for lobster '*i*', i.e. there may be numerous moulting seasons linked to lobster '*i*';
ρ	is a slope parameter;
$r(a_i, m)$	is the interaction effect of area a_i and moult season *m*, treated as a random effect, assumed to be normally distributed about zero with variance ϕ^2 ;
$l_i^-(m)$	is the size of the lobster in moulting season m prior to moulting;
$\hat{g}_i(m)$	is growth realized by lobster *i* in moulting season m ; this notation is necessary because a lobster may experience a number of moults while at large, and so growth rates specific to each of these moults have to be accounted for;

μ is an intercept parameter;

ε_i is process error due to natural variation in growth rate for the *i*-th lobster for the *m*-th moulting season, assumed to be normally distributed with a variance of σ_g^2; and

ζ_i is measurement error, assumed to be normally distributed with a variance of σ_m^2. This is only relevant when the lobster is recaptured, and should be omitted when one is considering intermediate moults between the moult season of release and recapture.

4.4 Growth over multiple moults and the propagation of growth variance

A consequence of the equation for growth rate given above is that, in the absence of any measurement error (where *m+1* represents the moulting season after moulting season *m*):

$$l_i^-(m+1) = l_i^-(m) + \hat{g}_i(m, a_i, l_i^-(m)) + \varepsilon_i(m) \tag{A2.13}$$

Successive increments in growth are represented as follows:

$$l_i^-(m+2) = l_i^-(m+1) + \hat{g}_i(m+1, a_i, l_i^-(m+1)) + \varepsilon_i(m+1) \tag{A2.14}$$

which can be rewritten as:

$$\begin{aligned} l_i^-(m+2) = [l_i^-(m) + \hat{g}_i(m, a_i, l_i^-(m)) + \varepsilon_i(m)] + \hat{g}_i(m+1, a_i, [l_i^-(m) + \\ \hat{g}_i(m, a_i, l_i^-(m)) + \varepsilon_i(m)]) + \varepsilon_i(m+1) \end{aligned} \tag{A2.15}$$

The latter simplifies to:

$$\begin{aligned} l_i^-(m+2) = [l_i^-(m) + \hat{g}_i(m, a_i, l_i^-(m))] + \hat{g}_i(m+1, a_i, [l_i^-(m) + \\ \hat{g}_i(m, a_i, l_i^-(m))]) + \varepsilon_i(m+1) + (1 + \rho\varepsilon_i(m)) \end{aligned} \tag{A2.16}$$

The cumulative somatic growth over two moulting seasons is therefore given by:

$$\begin{aligned} l_i^-(m+2) - l_i^-(m) &= [\hat{g}_i(m, a_i, l_i^-(m))] + \hat{g}_i(m+1, a_i, [l_i^-(m) + \\ &\quad \hat{g}_i(m, a_i, l_i^-(m))]) + \varepsilon_i(m+1) + (1 + \rho\varepsilon_i(m)) \\ &= \hat{G}_i + \varepsilon_i(m+1) + (1 + \rho\varepsilon_i(m)) \end{aligned} \tag{A2.17}$$

The above form for the cumulative growth is the sum of the error free model calculated cumulative growth plus an error term involving the model error values for each moult increment contributing to the cumulative growth. The form of this error term w.r.t. the error free cumulative growth from the model propagates in the following way for 1, 2, 3 or more moults:

- Error term for 1 moult: $\varepsilon_i(m)$
- Error term for 2 moults: $\varepsilon_i(m+1) + \varepsilon_i(m) + \rho\varepsilon_i(m)$
- Error term for 3 moults: $\varepsilon_i(m+2) + \varepsilon_i(m+1)[1+\rho] + \varepsilon_i(m)[1+\rho][1+\rho]$

The last expression indicates a general rule for the propagation of the error in terms of the $\varepsilon_i(m)$ and ρ values. If the model errors $\varepsilon_i(m)$ for successive moults are i.i.d. with variance σ_g^2 then the error terms are also normally distributed with variances given by:

- Variance of error term for 1 moult: σ_g^2
- Variance of error term for 2 moults: $\sigma_g^2 + [1+\rho]\sigma_g^2$
- Variance of error term for 3 moults: $\sigma_g^2 + [1+\rho]\sigma_g^2 + [1+\rho][1+\rho]\sigma_g^2$

Let $Var(G_i)$ be the variance of the cumulative growth G_i. If measurement error has a variance σ_m^2 then this must be included in $Var(G_i)$. Let $G_i(3)$ be the growth that arises from three consecutive moults; then the variance in this cumulative growth would be:

$$Var(G_i(3)) = \sigma_g^2 + [1+\rho]\sigma_g^2 + [1+\rho][1+\rho]\sigma_g^2 + \sigma_m^2 \qquad \text{(A2.18)}$$

The variance of the cumulative growth rate from n moults, $G_i(n)$, is given as:

$$Var(G_i(n)) = \left(\sum_{r=0}^{n-1} \sigma_g^2 [1+\rho]^{2r}\right) + \sigma_m^2 \qquad \text{(A2.19)}$$

4.5 The likelihood function

The probability density for G_i for Cases A, B, C and D given the model parameters is proportional to the following quantities:

Case A: $$\frac{pmoult(A) e^{\frac{-(G_i - \hat{G}_i(A))^2}{2Var(G_i(A))}}}{\sqrt{Var(G_i(A))}}$$

Case B: $$\frac{pmoult(B) e^{\frac{-(G_i - \hat{G}_i(B))^2}{2Var(G_i(B))}}}{\sqrt{Var(G_i(B))}}$$

Case C: $$\frac{pmoult(C) e^{\frac{-(G_i - \hat{G}_i(C))^2}{2Var(G_i(C))}}}{\sqrt{Var(G_i(C))}}$$

Case D: $$\frac{pmoult(D) e^{\frac{-(G_i - \hat{G}_i(D))^2}{2Var(G_i(D))}}}{\sqrt{Var(G_i(D))}}. \qquad \text{(A2.20)}$$

The likelihood of the observed growth of G_i, $p(G_i)$, is proportional to the sum of the four terms listed above:

$$p(G_i) \propto \frac{pmoult(A)e^{\frac{-(G_i-\hat{G}_i(A))^2}{2Var(G_i(A))}}}{\sqrt{Var(G_i(A))}} + \frac{pmoult(B)e^{\frac{-(G_i-\hat{G}_i(B))^2}{2Var(G_i(B))}}}{\sqrt{Var(G_i(B))}} + \frac{pmoult(C)e^{\frac{-(G_i-\hat{G}_i(C))^2}{2Var(G_i(C))}}}{\sqrt{Var(G_i(C))}} + \frac{pmoult(D)e^{\frac{-(G_i-\hat{G}_i(D))^2}{2Var(G_i(D))}}}{\sqrt{Var(G_i(D))}} \qquad \text{(A2.21)}$$

The overall likelihood for the observed dataset, LF, is equal to the product of likelihoods for all individual observations of G_i, i.e.:

$$LF \propto \coprod_{i=1}^{N} \left[\frac{pmoult(A)e^{\frac{-(G_i-\hat{G}_i(A))^2}{2Var(G_i(A))}}}{\sqrt{Var(G_i(A))}} + \frac{pmoult(B)e^{\frac{-(G_i-\hat{G}_i(B))^2}{2Var(G_i(B))}}}{\sqrt{Var(G_i(B))}} + \frac{pmoult(C)e^{\frac{-(G_i-\hat{G}_i(C))^2}{2Var(G_i(C))}}}{\sqrt{Var(G_i(C))}} + \frac{pmoult(D)e^{\frac{-(G_i-\hat{G}_i(D))^2}{2Var(G_i(D))}}}{\sqrt{Var(G_i(D))}} \right] \qquad \text{(A2.22)}$$

The objective function is then given by:

$$F = -\ln(LF) + d\ln(\phi) + \sum_a \sum_m \frac{[r(a,m)]^2}{2\phi^2} \qquad \text{(A2.23)}$$

where d is the number of active random effects, i.e. the number of area (a) and moult-season (m) combinations for which lobsters in the dataset are at large, and ϕ indicates the standard deviation of the random effects which is estimated when minimising the objective function.

4.6 Method of estimation

The parameter estimates used to produce standardized growth rates are the marginal posterior modes (penalised maximum likelihood estimates).

5. Standardization of 70mm growth rates for input into the assessments

The standardised 70mm growth for moult season m in a particular super-area is calculated by:

$$\hat{g}_{70}(m) = \mu + \overline{A} + M(m) + \rho.70 \qquad \text{(A2.24)}$$

where:

$\overline{A}$ is the median area factor for sub-areas in the super-area;

$M(m)$ is the season factor for season m; and

ρ is the slope parameter.

The spatially aggregated growth estimates are obtained from Model 1, standardized using the Dassen Island area factor from equation A2.12.

The spatially disaggregated estimates are obtained as follows:

- For Area 8 – 14 (Cape): using Model 1, standardized using the median area factor for sub-areas within this zone.
- For Area 3 – 6 (West): using Model 1, standardized using the median area factor for sub-areas within this zone.
- For Area 3 – 4 (West1): using Model 1, standardized using the median area factor for sub-areas within this zone.
- For Area 5 – 6 (West2): using Model 1, standardized using the median area factor for sub-areas within this zone.
- For Area 7 (Dassen): using Model 2b. (There is only one area factor.) Season factors are estimated for the seasons 1985 to 2004. The 70mm growth increments for seasons 1967 to 1984 are extrapolated as an average of those for 1985 to 2004.
- For Area 1-2 (North): using Model 3b, standardized using the median area factor for sub-areas within this zone. Season factors are not estimated for years 1974 to 1978 and 1981 to 1983. For these seasons, the 70mm growth increments are interpolated linearly from 1973 to 1979 and from 1980 to 1984.
- In all areas, the growth increments for seasons 1967 and earlier assumed to be the averages of those for 1968 to 2004 in the area concerned.

Table A2.1 Area classification.

Super-Area	Macro-Area	Area	Sub-Area
NORTH	Port Nolloth	Area 1	**PN2**
		Area 1	**PN3**
		Area 1	**PN4**
		Area 1	**PN5**
		Area 1	**PN6**
	Hondeklip Bay	Area 2	**HKB**
WEST 1	Elands Bay	Area 3	**EB**
	Lamberts Bay	Area 4	**LB1**
		Area 4	**LB2**
		Area 4	**LB3**
		Area 4	**LB4**
		Area 4	**LB5**
WEST 2	Saldanha Bay	Area 6	**SAL1**
		Area 6	**SAL2**
	St Helena Bay	Area 5	**ST1**
		Area 5	**ST2**
		Area 5	**ST3**
		Area 5	**ST4**
DASSEN	Dassen Island	Area 7	**DI**
CAPE	Cape Peninsula	Area 8	**CP1**
			CP2
			CP3
			CP4
			CP5
			CP6
	Robben Island	Area 9	**RI**
	Knol	Area 10	**HB**
	Walker Bay	Area 12	**WB1**
		Area 13	**WB2**
		Area 14	**WB3**

Appendix 3: Trap CPUE analyses for inputs to the OMP

Introduction

Generalized Linear Models (GLMs) have been applied to standardize the past commercial trapboat CPUE data from each super-area in which trapboat fishing takes place, namely Areas 3-8.

Basic data

The past trapboat dataset covers the period 1981-2006, the 2006 data being partial since at the time the analyses were conducted the fishing season was still underway.

Tables A3.1-4 indicate the sample sizes per season and month for each of the super-areas for these past seasons. The shaded areas indicate the data which were considered in the GLM analyses, with the lighter portion of the shaded area indicating the core information contributing to the final index of abundance for those models that include season/month interactions. It should be noted that data from any cells with a sample size ≤ 5 were excluded from the analyses. The rest of the data that were excluded were a consequence of small sample sizes or absence of data in many seasons or months. A listing of all data exclusions applied in readying these past data for analysis purposes is supplied in Annexure 3A.

The selection of the forms for the GLMs

Forward stepwise regression analyses were applied to the CPUE data (after the application of exclusions) from each of the super-areas. Decisions to include/exclude factors from the models were based on a rule where a factor was retained if it contributed to increasing r^2 by one or more percentage points. Interpolation was used to fill empty interaction cells where applicable. This involved taking the average of the parameter estimates from cells surrounding the empty cell, e.g. as shown in the table below, the cells marked with X would be used to interpolate the value for the empty season/month interaction cell.

	Month		
Season	**Jan**	**Feb**	**Mar**
1993		X	
1994	X	Empty cell	X
1995		X	

The final models selected for each super-area are shown in Table A3.5. Diagnostic tests related to the studentized residuals obtained from each of the super-area GLMs indicated that the assumption of normality was not met. This was addressed by re-running the respective models, but excluding data corresponding to residuals exceeding ±2 standard deviations.

The equations applied to obtain the super-area specific standardized CPUE indices are shown in Table A3.6. Given that the final model for Area 3+4 contains an interaction with Area it is necessary to integrate over the size of the Area in order to obtain an index of abundance. Also, the size of Area 8 increased over time (1987 - 1995) to include East of Hangklip to allow for indications of an expansion of the population into this area over that period. For this reason the size of the Area is taken into account in calculating the Area 8 standardized indices. The Area sizes are shown in Table A3.7.

The resulting standardized trapboat CPUE indices for each super-area at the time of this analysis are shown in Table A3.8 and Figures A3.1a-d respectively.

Extension for future seasons to provide OMP input

The OMP envisages future commercial trap CPUE data becoming available for super-areas 7 and 8 only.

The GLMs applied to provide the time series required will respect the following:

a) they will include co-variates as specified in Table A3.5, and calculate indices from the GLM outputs as indicated in Tables A3.6 and A3.7 (note that this means that values for past seasons shown in Table A3.8 will be updated slightly each season);
b) the cut-off date for data to be used for these GLM analyses will be 30 June of year 20xx for recommendations for the 20xx/20(xx+1) season; the analyses will be restricted to data up to and including the 20(xx-2)/20(xx-1) season;
c) the procedure described above to interpolate any missing values for the season-month interaction cells will be as described above;
d) the procedure for excluding outliers (related to the studentized residuals) will be as specific above; and
e) there must be more than five data points for estimation of a season-month interaction term to be attempted within the GLM.

Table A3.1: Area 3+4 trapboat sample sizes per season and month to 2005 and for part of 2006. The shaded areas together indicate the data included in the GLM analyses. The portion in the lighter shaded area contributes to developing a final index of abundance given the inclusion of a season/month interaction. Cells where the number of data points *n* ≤ 5 are also excluded from the analyses.

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Total
1981	1318	512	160	61						2051
1982	1316	496	53	3						1868
1983	599	140	57	54						850
1984	586	251	228	97						1162
1985	404	119	90	30						643
1986	544	340	145	26	56	29	118	24		1282
1987	700	187	164	75	6					1132
1988	689	245	298	252	131	33				1648
1989	493	527	436	280	289	135	181	43		2384
1990	1301	977	1266	722	727	521	135	5		5654
1991	1552	993	901	385	398	176	68			4473
1992	560	353	147	10						1070
1993	313	514	244							1071
1994	524	736	744	428	350	91	8			2881
1995	413	203	75	65			6			762
1996	142	175	93	87	20	3			71	591
1997		29	103	15	17	1				165
1998		41	6	15	56	5				123
1999		101	82	18	9					210
2000		47	141	128	63					379
2001		13	90	30	15	18	19	7		192
2002					1		11	15	2	29
2003		6	1	2	24		14	5		52
2004	1		13	15	9	9	10	6		63
2005					8	15				23
2006			1							1
Total	11455	7005	5538	2798	2179	1036	570	105	73	30759

Table A3.2: Area 5+6 trapboat sample sizes per season and month to 2005 and for part of 2006. The shaded areas together indicate the data included in the GLM analyses. The portion in the lighter shaded area contributes to developing a final index of abundance given the inclusion of a season/month interaction. Cells where the number of data points *n* ≤ 5 are also excluded from the analyses.

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Total
1981	1895	883	391	152	5					3326
1982	1331	528	551	418	414	43				3285
1983	1187	299	220	81	32					1819
1984	1292	345	234	204	65					2140
1985	1290	270	191	24						1775
1986	1130	722	324	191	177	93	143	7		2787
1987	1256	393	152	92	2	5				1900
1988	567	364	328	109	173	257	78	3		1879
1989	464	384	518	348	221	55	131	34		2155
1990	810	677	466	395	305	224	109	38		3024
1991	1203	794	467	176	67	223	150	3		3083
1992	844	680	648	296	81	15	24	2		2590
1993	329	573	404	114	44	1	1			1466
1994	163	319	127	61	115	24	1			810
1995	111	188	64	14						377
1996	149	147	66						11	373
1997	60	142	70	28	50				1	351
1998		3	14		63	16	4			100
1999		14	30	9	2					55
2000			2	10						12
2001				1	19	1	3			24
2003				1	2					3
2004		1			1			2		4
Total	14081	7726	5267	2724	1838	957	644	89	12	33338

Table A3.3: Area 7 trapboat sample sizes per season and month to 2005 and for part of 2006. The shaded areas together indicate the data included in the GLM analyses. The portion in the lighter shaded area contributes to developing a final index of abundance given the inclusion of a season/month interaction. Cells where the number of data points $n \leq 5$ are also excluded from the analyses.

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Total
1981	1032	365	35	15								1447
1982	609	156	59	40	43							907
1983	383	217	156	140								896
1984	404	138	82	106	30							760
1985	234	125	68	103	20							550
1986	243	485	386	184	159	33	49	2				1541
1987	421	152	147	224	208	92	18					1262
1988	189	165	169	223	137	116	92	104				1195
1989	47	251	274	131	110	58	57	128				1056
1990	55	210	460	293	90	238	105	4				1455
1991	252	310	276	32		74	194	4				1142
1992	22	199	391	227	80	5						924
1993	79	159	278	195	70	9	18					808
1994	133	252	365	291	172	30	15	20				1278
1995	68	223	206	199	59	2						757
1996	74	216	112	73	42	7	27	5	80	4		640
1997	12	148	279	394	220	96	46	2				1197
1998		81	117	105	209	145	155	171	3			986
1999		207	243	256	218	30	44	22				1020
2000		117	240	247	215	160	68	7				1054
2001		60	133	305	219	175	86	102				1080
2002	31	164	239	121	216	159	393	475				1798
2003	96	246	455	277	278	209	178	150	53			1942
2004	13	473	536	504	290	259	143	186				2404
2005		474	529	447	86	207	231	32	1	81	158	2246
2006	98	487	599	621	331	83	175	117				2511
Total	4495	6080	6834	5753	3502	2187	2094	1531	137	85	158	32856

Table A3.4: Area 8 trapboat sample sizes per season and month to 2005 and for part of 2006. The shaded areas together indicate the data included in the GLM analyses. The portion in the lighter shaded area contributes to developing a final index of abundance given the inclusion of a season/month interaction. Cells where the number of data points $n \leq 5$ are also excluded from the analyses.

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Total
1981	594	368	435	148	11							1556
1982	332	394	372	205	117	18						1438
1983	350	278	349	49	70							1096
1984	331	203	1		26							561
1985	249	190	73	98	39	67	32	53				801
1986	157	227	327	296	168	57	27	32	5			1296
1987	50	51	174	207	103	83	87	87	14			856
1988	17	46	150	154	194	134	80	91	85			951
1989	24	12	103	107	145	85	54	6				536
1990		19	68	104	40	75	163	155	37			661
1991	68	209	338	287	313	199	208	132	21			1775
1992	4		45	204	208	224	283	159	62	61		1250
1993	4	21	10	119	176	213	247	127	290	145		1352
1994	4	27	226	247	190	301	207	138	72	55	13	1480
1995	5	22	49	81	269	184	236	160	125	54		1185
1996		5	110	136	207	215	158	207	427	109	7	1581
1997			43	61	94	179	412	337	253	149	54	1582
1998		18	28	36	164	175	171	258	359	241	248	1698
1999		8	22	63	106	374	316	239	172	144	90	1534
2000		1	9	24	136	165	275	283	202	110	125	1330
2001		2	10	28	78	221	172	235	342	571	621	2280
2002	4	24	33	53	75	152	151	221	356	364	608	2041
2003	7	12	48	77	309	301	344	277	382	391	306	2454
2004	19	25	19	81	214	245	319	411	424	500	670	2927
2005					90	177	168	762	390	270	342	2199
2006	14	41	46	53	327	348	688	246				1763
Total	2233	2203	3088	2918	3869	4192	4798	4616	4018	3164	3084	38183

Table A3.5: Final model to be applied to each super-area.

Super-area	Model
3+4	$ln\text{CPUE}=\alpha+\beta_{season}+\gamma_{month}+\kappa_{Area}+(season\times month)+(season\times Area)+\varepsilon$
5+6	$ln\text{CPUE}=\alpha+\beta_{season}+\gamma_{month}+(season\times month)+\varepsilon$
7	$ln\text{CPUE}=\alpha+\beta_{season}+\gamma_{month}+(season\times month)+\varepsilon$
8	$ln\text{CPUE}=\alpha+\beta_{season}+\gamma_{month}+(season\times month)+\varepsilon$

Table A3.6: Equations applied to obtain final indices of abundance for each super-area. A_a indicates Area size, the values of which are shown in Tables 7.

Super -area	Equation
Area 3+4	$CPUE_{season}=(\sum_{month=Dec}^{Feb}(\sum_{Area=3}^{4} e^{(\alpha+\beta_{season}+\gamma_{month}+\kappa_{Area}+(season\times month)+(season\times Area))})\times A_a)/\sum_{month=D}^{Feb}$
Area 5+6	$CPUE_{season}=(\sum_{month=Nov}^{Feb} e^{(\alpha+\beta_{season}+\gamma_{month}+season\times month)})/\sum_{month=Nov}^{Feb}1$
Area 7	$CPUE_{season}=(\sum_{month=Dec}^{Mar} e^{(\alpha+\beta_{season}+\gamma_{month}+season\times month)})/\sum_{month=Dec}^{Mar}1$
Area 8	$CPUE_{season}=(\sum_{month=Jan}^{June} e^{(\alpha+\beta_{season}+\gamma_{month}+season\times month)})\times A_8/\sum_{month=Jan}^{June}1$

Table A3.7: Area sizes (km^2) applied to Areas 3, 4 and 8. The sizes of Areas 3 and 4 include Marine Protected Areas (which was not the case before for the area-aggregated analyses). It is assumed that the area size for Area 8 increased in a linear fashion over the period 1987 – 1995 so that the area East of Hangklip could be incorporated for the period when lobsters moved into this area.

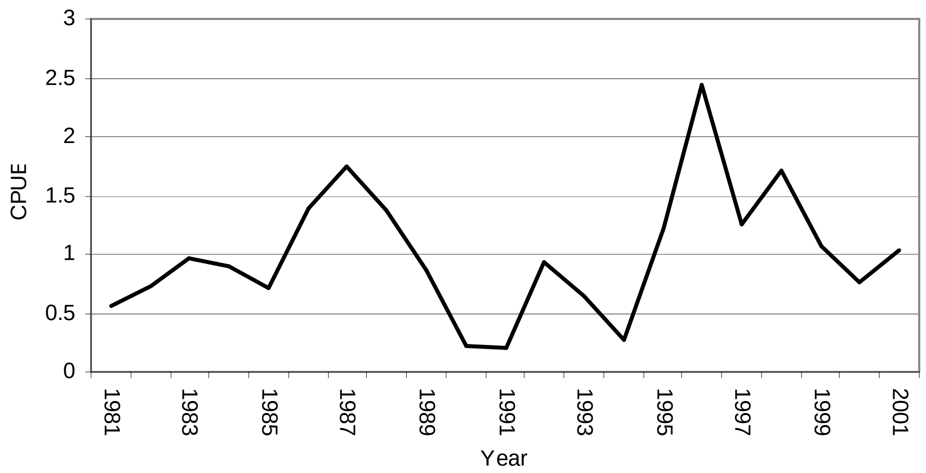
Area	Season	Area size (km^2)
3	n/a	1141
4	n/a	2375
8	≤ 1986	2621
	1987	2761
	1988	2901
	1989	3042
	1990	3182
	1991	3322
	1992	3462
	1993	3603
	1994	3743
	≥ 1995	3883

Table A3.8: Trapboat standardized CPUE per super-area for analyses using data up to 2005 and for part of 2006. Each index has been normalized to its mean.

Season	Area 3+4	Area 5+6	Area 7	Area 8
1981	0.561	1.058	0.879	
1982	0.736	1.056	1.088	
1983	0.970	1.205	0.961	
1984	0.892	1.429	1.280	
1985	0.706	1.611	1.270	0.564
1986	1.394	1.123	0.804	0.777
1987	1.745	1.318	0.967	0.680
1988	1.380	1.462	1.081	0.793
1989	0.866	1.090	0.886	0.701
1990	0.216	0.640	0.263	0.333
1991	0.207	0.290	0.160	0.585
1992	0.926	0.677	0.454	0.884
1993	0.648	1.202	0.565	0.927
1994	0.271	0.493	0.291	0.879
1995	1.214	1.039	0.566	1.071
1996	2.437	0.572	1.035	1.033
1997	1.260	0.735	1.246	1.045
1998	1.714		1.574	1.041
1999	1.060		1.285	1.124
2000	0.768		1.383	1.280
2001	1.031		2.235	1.499
2002			1.711	1.747
2003			1.531	1.224
2004			1.171	1.195
2005			0.591	1.311
2006			0.726	1.308

Figures A3.1a-b: Trapboat standardized CPUE indices per super-area for analyses using data to 2005 and part of 2006. Each index has been normalized to its mean.

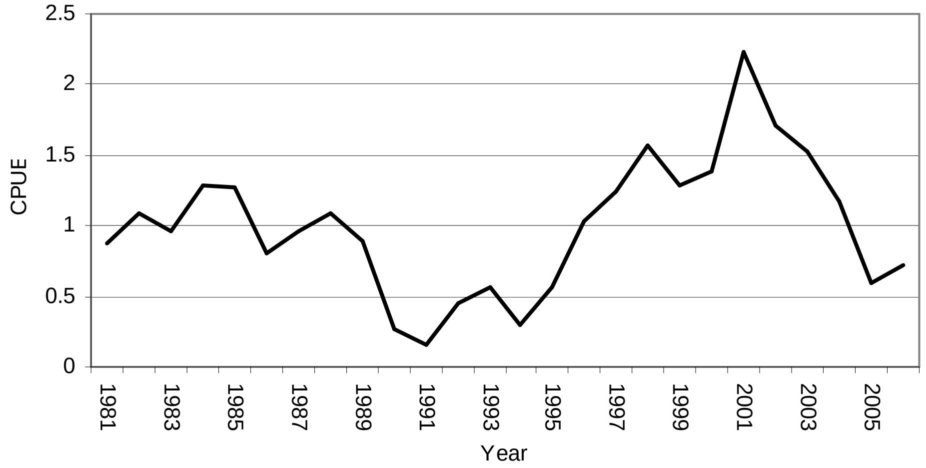
a) Area 3+4



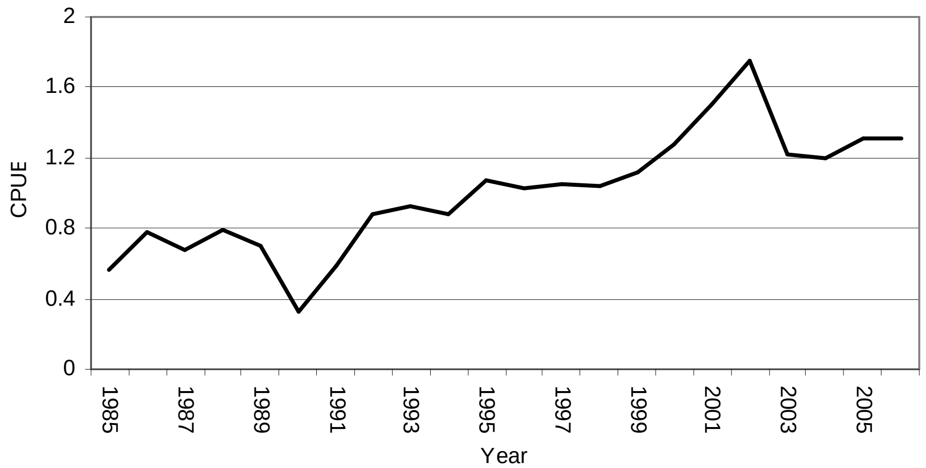
b) Area 5+6

Figures A3.1c-d: Trapboat standardized CPUE indices per super-area for analyses using data to 2005 and part of 2006. Each index has been normalized to its mean.

c) Area 7



d) Area 8



Annexure 3A

A listing of all data exclusions applied prior to the analysis of the data

A. General exclusions (across all Areas)

1. Vessels that fished for Hout Bay Fishing over the period 1997-2000, namely CTA68, CTA211, KB34, CTA437, CTA626, CTA101, HTB48, CTA36, KB23, CTA111, HTB167, KB16, K21, CTA143, CTA127, CTA106, CTA174, KB1, CTA394, KB89 and CTA149
2. Month=October
3. Pull (effort) = 0
4. Catch = 0
5. Area < 3
6. Area > 8

B. Super-area specific exclusions

Area 3+4

1. All records not pertaining to Area 3 or 4
2. Season > 2001 (patchy data)
3. June and July (patchy data)
4. February 1982 (n≤5)
5. April 1996 - 1998 (n≤5)

Area 5+6

1. All records not pertaining to Area 5 or 6
2. Season > 1997 (patchy data)
3. June and July (patchy data)
4. March 1981 (n≤5)
5. March 1987 (n≤5)
6. April 1987 (n≤5)
7. April 1993 (n≤5)
8. May 1993 (n≤5)
9. May 1994 (n≤5)

Area 7

1. All records not pertaining to Area 7
2. July-Sept (patchy data)
3. June 1986 (n≤5)
4. June 1990 (n≤5)
5. June 1991 (n≤5)
6. April 1992 (n≤5)
7. April 1995 (n≤5)
8. June 1996 (n≤5)
9. June 1997 (n≤5)

Area 8

1. All records not pertaining to Area 8
2. Season < 1985
3. July 1986
4. November in seasons 1992-1995
5. December 1996
6. December 2000
7. December 2001
8. November 2002

Appendix 4: Hoopnet CPUE analyses for inputs to the OMP

Introduction

A Generalized Linear Mixed Model (GLMM) has been applied to standardize the commercial hoopnet CPUE data from super-area 1-2, while Generalized Linear Models (GLMs) have been applied to the CPUE data from each of the other super-areas in which hoopnet fishing takes place, namely Areas 3-6 and Area 8.

Basic data

There are two sources of hoopnet data, namely bakkies and deckboats. The following should be noted about these data:

1. *Deckboat effort is defined as the number of nets used per deckboat. CPUE is therefore defined as catch/net.*
2. *Bakkie effort is defined as a bakkie day. CPUE is therefore defined as catch/bakkie day. The data are recorded differently for the periods 1986 – 1991 and 1992 onwards. For the former period each record gives the total catch for all bakkies that fished on a given day (i.e. CPUE = catch/number of bakkies), whereas for the latter period each record corresponds to a single bakkie day (i.e. CPUE = catch).*

The data for super-area 1-2 and 3-8 have historically been treated separately as a result of trends being substantially different in super-area 1-2 compared to those of the other Areas.

The past hoopnet dataset for super-area 1-2 covers the period 1971 – 2006, although the analyses only take into account the data from 1993 since it is only from that season that detailed, reliable information is available. The dataset for Areas 3-8 covers the period 1981-2006. For both super-area 1-2 and Areas 3-8 the 2006 data are partial since at the time the analyses were conducted the fishing season was still underway.

Table A4.1 indicates the sample sizes per season and month for super-area 1-2 for the past seasons, while the nominal CPUE index is shown in Table A4.2.

Tables A4.3-6 indicate the sample sizes per season and month for Areas 3-8 respectively. The shaded areas indicate the data which were considered in the GLM analyses, with the lighter portion of the shaded area indicating the core information contributing to the final index of abundance for those models that include season/month interactions. It should be noted that data from any cells with a sample size ≤ 5 are excluded from the analyses. The rest of the data that were excluded were a consequence of small sample sizes or absence of data in many seasons or months. A listing of all data exclusions applied in readying these past data for analysis purposes is supplied in Annexure 4A.

During the development of the GLMs for each of the Area 3-8 super-areas it was agreed that only the bakkie data would be used, except in the case of Area 3-4 where the deckboat data are included to allow for a longer time series since a fair amount of deckboat fishing took place in these Areas.

The selection of the forms for the GLMM and GLMs

A GLMM has been applied to the super-area 1-2 data, with the season/month interaction being treated as a random effect. The pre-1993 nominal CPUE data are scaled to the GLMM index by multiplying each value by the ratio:

$$\frac{\overline{CPUE_{glmm,1993-2005}}}{\overline{CPUE_{bakkie\ nominal,1993-2005}}}.$$

Forward stepwise regression analyses were applied to the CPUE data (after the application of exclusion rules) from each of the other super-areas. Decisions to include/exclude factors from the models were based on a rule where a factor was retained if it contributed to increasing r^2 by one or more percentage points. Interpolation was used to fill empty interaction cells where applicable. This involved taking the average of the parameter estimates from cells surrounding the empty cell, i.e. as shown in the table below, the cells marked with X would be used to interpolate the value for the empty season/month interaction cell:

	Month		
Season	**Jan**	**Feb**	**Mar**
1993		X	
1994	X	Empty cell	X
1995		X	

The final models selected for each super-area are shown in Table A4.7. Diagnostic tests related to the studentized residuals obtained from each of the super-area GLMs indicated that the assumption of normality was not met. This was addressed by re-running the respective models, but excluding data corresponding to residuals exceeding ±2 standard deviations for super-area 5-6 and ±1 standard deviation for super-area 3-4 and 8.

The equations applied to obtain the super-area specific standardized CPUE indices are shown in Table A4.8. Given that the final model for super-area 5-6 contains an interaction with Area it is necessary to integrate over the size of the Area in order to obtain an index of abundance. Also, the size of Area 8 increased over time (1987 - 1995) to include East of Hangklip to allow for indications of an expansion of the population into this area over that period. For this reason the size of the Area is taken into account in calculating the Area 8 standardized indices. The Area sizes are shown in Tables A4.9 and A4.10 respectively.

The resulting standardized hoopnet CPUE index for super-area 1-2 is shown in Figure A4.1, while those for super-areas 3-4, 5-6 and 8 are shown in Figure A4.2.

Extension for future seasons to provide OMP input

The OMP envisages future commercial hoopnet CPUE data becoming available for super-areas 1-2, 3-4, 5-6 and 8.

The GLMM and GLMs applied to provide the time series required will respect the following:

f) they will include co-variates as specified in Table A4.5, and calculate indices from the GLM outputs as indicated in Tables A4.6 and A4.7 (note that this means that values for past seasons shown in Table A4.8 will be updated slightly each season);
g) the cut-off date for data to be used for these GLM analyses will be 30 June of year 20xx for recommendations for the 20xx/20(xx+1) season; the analyses will be restricted to data up to and including the 20(xx-2)/20(xx-1) season;
h) the procedure described above to interpolate any missing values for the season-month interaction cells will be as described above;
i) the procedure for excluding outliers (related to the studentized residuals) will be as specific above; and
j) there must be more than five data points for estimation of a season-month interaction term to be attempted within the GLM.

Reference

van Zyl, D. 2006. West Coast rock lobster annual TAC, catch, effort and CPUE per Area. Unpublished MCM Working Group Document, WCL/07/06/WCRL26. 6pp.

Table A4.1: Area 1-2 hoopnet (bakkie+deckboat) sample sizes per season and month to 2005 and for part of 2006 (after the exclusion of outliers as reported in Annexure 4A).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total
1993		266	335	478	277	181			1537
1994	94	388	202	234	313	164			1395
1995	134	253	278	143	152	50			1010
1996	1	267	260	252	40	20		26	866
1997		100	211	194	340	192	106		1143
1998				147	7	76	66	8	304
1999				161	167	172	41		541
2000				361	174	162	125		822
2001				36	260	105	210		611
2002		11	51	275	328	140	69		874
2003	88	208	127	414	174	141	46		1198
2004	58	296	91	408	146	111	54		1164
2005				160	236	155	130	9	690
2006	2	323	184	185	105	94	35		928
Total	377	2112	1739	3448	2719	1763	882	43	13083

Table A4.2: Area 1-2 nominal bakkie CPUE series (van Zyl, 2006).

Season	CPUE (catch/bakkie)
1974	
1975	
1976	22.45
1977	14.77
1978	19.64
1979	19.43
1980	22.14
1981	26.08
1982	
1983	
1984	
1985	31.64
1986	24.53
1987	42.44
1988	21.78
1989	18.31
1990	14.62
1991	14.41
1992	19.86
1993	18.65
1994	14.10
1995	21.23
1996	25.12
1997	20.12
1998	15.75
1999	11.62
2000	15.97
2001	17.94
2002	22.95
2003	21.16
2004	20.14
2005	23.32

Table A4.3: Area 3-4 hoopnet (bakkie+deckboat) sample sizes per season and month to 2005 and for part of 2006. The shaded areas together indicate the data included in the GLM analyses. The portion in the lighter shaded area contributes to developing a final index of abundance given the inclusion of a season/month interaction. Cells where the number of data points *n* ≤ 5 are also excluded from the analyses.

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
1981	123	31	96	107	39						396
1982	95	226	20		37	34					412
1983	237	101	13	10							361
1984	282	146	102	14							544
1985	162	111	152	39							464
1986	254	214	170	38	92	24	26			1	819
1987	535	256	181	140	23						1135
1988	518	214	192	139	139	59					1261
1989	111	153	242	208	183	63	17	1			978
1990	172	136	120	201	188	104	16	1			938
1991	243	156	148	64	46	15	20				692
1992	1459	1083	76	25	23						2666
1993	780	1406	821	8							3015
1994	676	779	601	1078	1497	426	55				5112
1995	852	488	336	155	2						1833
1996	373	542	851	417	59	2			6		2250
1997	102	1025	450	13	181		15				1786
1998		376	116	256	193	50	123				1114
1999		405	953	82	290	100	2				1832
2000		79	718	409	42						1248
2001		66	274	216	11	148	112	9			836
2002	3	129	375	370	143	385	505	351	110		2371
2003	170	222	436	274	309	87	17	1			1516
2004	281	263	468	494	188	80	24	66			1864
2005			39	179	419	807	68	62			1574
2006	20	36	153	208	300	154	70	15			956
Total	7448	8643	8103	5144	4404	2538	1070	506	116	1	37973

Table A4.4: Area 5-6 hoopnet (bakkies only) sample sizes per season and month to 2005 and for part of 2006. The shaded areas together indicate the data included in the GLM analyses. The portion in the lighter shaded area contributes to developing a final index of abundance given the inclusion of a season/month interaction. Cells where the number of data points $n \leq 5$ are also excluded from the analyses.

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
1986	51	24	45	20	10	6	9		165
1987	362	88	7						457
1988	100	34	35	1	28	31	14	4	247
1989	45	15	27	29	25	12	2	1	156
1990	70	55	45	23	36	39	2		270
1991	107	88	67	44	28	30	6		370
1992	866	494	202	109	114	8			1793
1993	171	299	418	226	282	218	35		1649
1994	172	207	216	170	34				799
1995	112	174	138						424
1996	136	240	252	34					662
1997	80	250	214	116		1			661
1998		70	199						269
1999		148	221	166	28				563
2000		116	232						348
2001			3	57	51	111	77	50	349
2002		16	22	123	186	329	360	233	1269
2003	23	104	280	227	123	47	69	120	993
2004	17	154	224	173	82	90	30	57	827
2005			14	55	60	73	55	51	308
2006	16	55	69	35	82	40	131	24	452
Total	2328	2631	2930	1608	1169	1035	790	540	13031

Table A4.5: Area 7 hoopnet (bakkies only) sample sizes per season and month.

	Nov	Jan	Feb	Mar	May	Total
1990		4	5	1	19	29
1991		29	11			40
1992	1	1				2
1995		2				2
1999		3				3
2000		1				1
Total	1	40	16	1	19	77

Table A4.6: Area 8 hoopnet (bakkies only) sample sizes per season and month to 2005 and for part of 2006. The shaded areas together indicate the data included in the GLM analyses. The portion in the lighter shaded area contributes to developing a final index of abundance given the inclusion of a season/month interaction. Cells where the number of data points *n* ≤ 5 are also excluded from the analyses.

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1986	14	12	22	20	21	18	3	3				113
1987	5	9	20	14	16	8	6	3				81
1988	5	13	12	20	22	11						83
1989	7	10		7	11		5	9				49
1990	1	5	13	13	14	17	11					74
1991	6	10	14	9	11	4	1					55
1992	53	111	38	141	172	73	77	86				751
1993	46	95	106	158	160	163	115	65	8			916
1994	64	136	199	129	115	12	114	119	5			893
1995	85	56	66	120	125	96	14	13		18		593
1996	66	69	130	36	87	102	15		91	29		625
1997		48	37	69	85	41	77	55	61	35	25	533
1998		33	27	20	102	38	83	56	74	71	51	555
1999		59	54	66	58	122	104					463
2000		44	101	44	53	63	82	52	3	5		447
2001			26	29	87	124	262	407				935
2002	1	7	63	76	162	329	403	558	42		1	1642
2003	5	17	92	56	123	324	448	644				1709
2004	1	1	42	86	219	292	310	539	1		2	1493
2005				10	133	119	220	224				706
2006	8	41	45	97	187	139	335	265				1117
Total	367	776	1107	1220	1963	2095	2685	3098	285	158	79	13833

Table A4.7: Final model to be applied to each super-area.

Super-area	Model type	Data source	Model
1-2	GLMM	Bakkies + Deckboats	$ln\text{CPUE}=\alpha+\beta_{\text{season}}+\gamma_{\text{month}}+\tau_{\text{fishing type}}+(\text{season}\times\text{month})+\varepsilon$
3-4	GLM	Bakkies+Deckboats	$ln\text{CPUE}=\alpha+\beta_{\text{season}}+\gamma_{\text{month}}+\tau_{\text{fishing type}}+(\text{season}\times\text{month})+\varepsilon$
5-6	GLM	Bakkies	$ln\text{CPUE}=\alpha+\beta_{\text{season}}+\gamma_{\text{month}}+\kappa_{\text{Area}}+(\text{season}\times\text{month})+(\text{season}\times\text{Area})+(\text{month}\times\text{Area})+\varepsilon$
8	GLM	Bakkies	$ln\text{CPUE}=\alpha+\beta_{\text{season}}+\gamma_{\text{month}}+(\text{season}\times\text{month})+\varepsilon$

Table A4.8: Equations applied to obtain final indices of abundance for each super-area. A_a indicates Area size, the values of which are shown in Tables A4.9 and A4.10.

Super-area	Equation
Area 1-2	$CPUE_{season} = e^{season}$
Area 3-4	$CPUE_{season} = \sum_{month=Dec}^{Feb} e^{(\alpha+\beta_{season}+\gamma_{month}+\tau_{bakkies}+season\times month)} \ / \ \sum_{month=Dec}^{Feb} 1$
Area 5-6	$CPUE_{season} = (\sum_{month=Dec}^{Jan} (\sum_{Area=5}^{6} e^{(\alpha+\beta_{season}+\gamma_{month}+\kappa_{Area}+(season\times month)+(season\times Area)+(month\times Area))}) \times A_a) / \sum_{month=Dec}^{Jan} 1$
Area 8	$CPUE_{season} = ((\sum_{month=Jan}^{Apr} e^{(\alpha+\beta_{season}+\gamma_{month}+season\times month)}) \times A_a) / \sum_{month=Jan}^{Apr} 1$

Table A4.9: Area sizes (km^2) applied to Areas 3-7 respectively. Note that these sizes include Marine Protected Areas in the calculation of the size of the habitat area (which was not the case in previous area-aggregated analyses).

Area 3	Area 4	Area 5	Area 6	Area 7
1141	2375	561	834	2851

Table A4.10: Area sizes (km^2) applied to Area 8. It is assumed that the area size for Area 8 increased in a linear fashion over the period 1987 – 1995 so that the area East of Hangklip could be incorporated into this area.

Season	Area size (km^2)
≤ 1986	2621
1987	2761
1988	2901
1989	3042
1990	3182
1991	3322
1992	3462
1993	3603
1994	3743
≥ 1995	3883

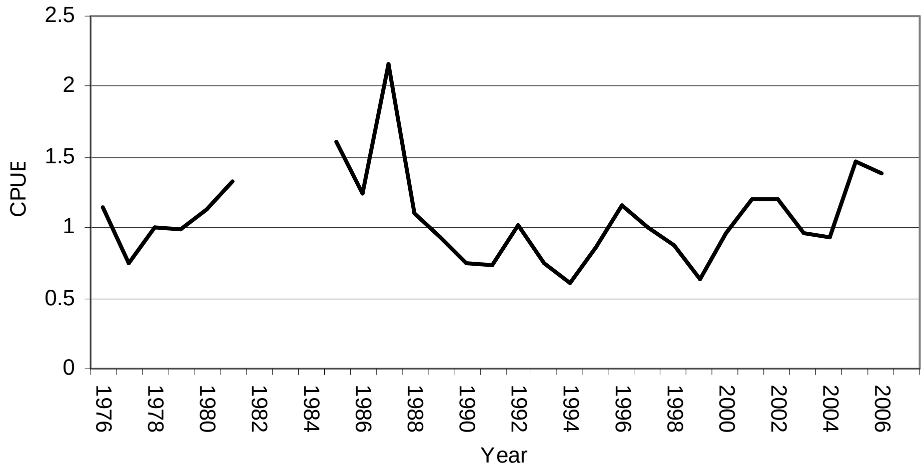
Table A4.11: Standardized CPUE index for Area 1-2. The GLMM index has been normalized to its mean, and the pre-1993 nominal bakkie CPUE data have been scaled to the GLMM index.

Season	Index
1976	1.142
1977	0.751
1978	0.999
1979	0.988
1980	1.126
1981	1.327
1982	
1983	
1984	
1985	1.609
1986	1.248
1987	2.159
1988	1.108
1989	0.931
1990	0.744
1991	0.733
1992	1.010
1993	0.752
1994	0.601
1995	0.861
1996	1.164
1997	1.007
1998	0.880
1999	0.641
2000	0.958
2001	1.201
2002	1.196
2003	0.954
2004	0.928
2005	1.474
2006	1.382

Table A4.12: Standardized CPUE index for Areas 3-8. Each index has been normalized to its mean.

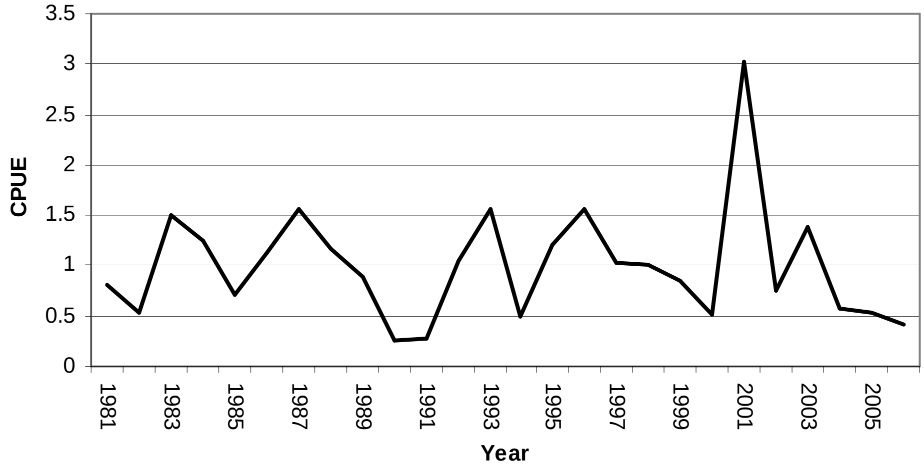
Season	Area 3-4 (bakkies+deckboats)	Area 5-6 (bakkies)	Area 8 (bakkies)
1981	0.818		
1982	0.543		
1983	1.505		
1984	1.238		
1985	0.703		
1986	1.130	1.989	0.230
1987	1.563		0.324
1988	1.171	2.042	0.386
1989	0.886	1.385	
1990	0.248	1.249	0.599
1991	0.270	0.659	0.326
1992	1.039	0.838	0.719
1993	1.553	0.633	0.838
1994	0.485	0.244	1.267
1995	1.198	0.456	1.372
1996	1.557	0.894	1.161
1997	1.023	0.860	1.405
1998	1.004	0.560	1.748
1999	0.857	0.891	1.577
2000	0.506	1.055	1.552
2001	3.024		1.495
2002	0.755	1.244	1.094
2003	1.382	0.778	0.975
2004	0.579	0.692	1.100
2005	0.540	1.446	0.884
2006	0.423	1.087	0.948

Figure A4.1: Standardized CPUE index for Area 1-2. The pre-1993 nominal bakkie CPUE data have been scaled to the GLMM standardized index.

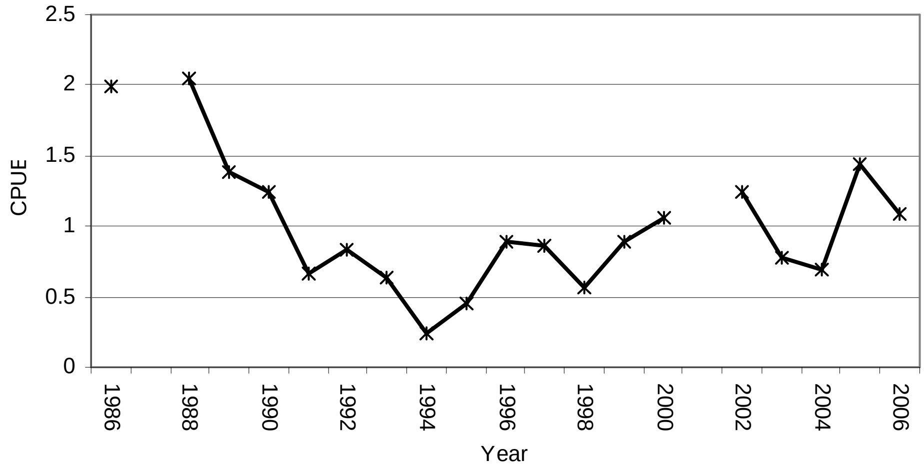


Figures A4.2a-c: Hoopnet standardized CPUE indices per super-area. Each index has been normalized to its mean.

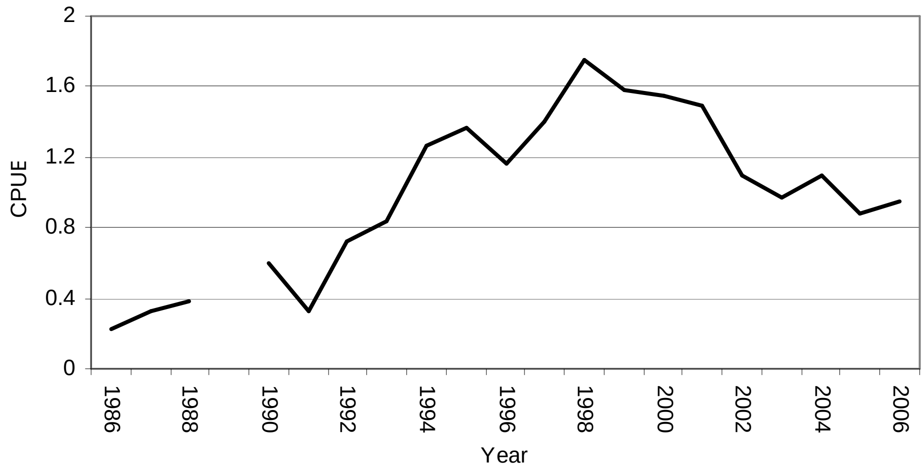
e) Area 3-4 (bakkies+deckboats)



f) Area 5-6 (bakkies)



g) Area 8 (bakkies)



Annexure 4A

Data exclusions applied to super-area 1-2 prior to the analysis of the data

1. Area > 2
2. Month=June (1 record)
3. Catch = 0

Data exclusions applied to Areas 3-8 prior to the analysis of the data

A. <u>General exclusions</u>

1. Records where bakkies = 90 over the seasons 1986-1991
2. Month=October
3. Nets = 0 (deckboat data)
4. Catch = 0
5. Area < 3
6. Area > 8

B. <u>Super-area specific exclusions</u>

Area 3-4

1. All records not pertaining to Area 3 or 4
2. June - August (patchy data)
3. March 1995 ($n \leq 5$)
4. April 1996 ($n \leq 5$)
5. May 1999 ($n \leq 5$)
6. November 2002 ($n \leq 5$)

Area 5-6

1. All records not pertaining to Area 5 or 6
2. June (patchy data)
3. Area = 6 and season = 1999 (small sample size – problematic in season/area interaction)
4. Season 1987 (patchy data)
5. Season 2001 (patchy data)
6. February 1988 ($n \leq 5$)
7. May 1989 ($n \leq 5$)
8. May 1990 ($n \leq 5$)
9. April 1997 ($n \leq 5$)

Area 8

1. All records not pertaining to Area 8
2. August and September (patchy data)
3. Season 1989 (patchy data)
4. May and June 1986 ($n \leq 5$)
5. June 1987 ($n \leq 5$)
6. November 1987 ($n \leq 5$)
7. November 1988 ($n \leq 5$)
8. November and December 1990 ($n \leq 5$)
9. April and May 1991 ($n \leq 5$)
10. July 1994 ($n \leq 5$)
11. July 2000 ($n \leq 5$)
12. November 2002 ($n \leq 5$)
13. November 2003 ($n \leq 5$)
14. November 2004 ($n \leq 5$)
15. December 2004 ($n \leq 5$)
16. July 2004 ($n \leq 5$)

Appendix 5 – FIMS analyses to provide inputs to the OMP.

At the time "OMP-2007 re-cast" was adopted, FIMS estimates (see Table A5.0 below) were provided by L. Scott (pers. commn, see Glazer 2007). In 2009 the methodology used was modified as set out below (Brandão and Butterworth 2009), with results given in Table A5.1 below.

Re-analysis of the Fisheries Independent Monitoring Survey of the Rock Lobster resource of South Africa

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August 2009

Introduction

Data from the FIMS surveys carried over the period 1992/93 to 2008/09 have been re-analysed here. This re-analysis was necessary because verification of the data resulted in several corrections. These corrections mainly involved differentiation of records that had a zero catch associated with them when in fact the trap had been lost or open or not set. The total area of each Zone as well as the area for each transect surveyed was also re-calculated (see van Zyl *et al.*, 2009). The allocation of stations to Hotspot areas changed in some cases from that in previous analyses. The methodology for calculating abundance indices has also been changed slightly.

Data

The FIMS data analysed covers the period 1992/93 to 2008/09. A data validation exercise resulted in several corrections made to the FIMS database. These changes were:

- differentiation between a true zero catch and a zero record which denoted a lost trap or a trap not set, or an open bag;
- zero catches recorded but lobsters had been measured; these records were replaced with estimates calculated from the mass of the catch;
- incorrect assignment of survey leg to records;
- correction of a few incorrect entries in the number of lobsters caught;
- reassignment of stations to Hotspots, and new area calculations for each surveyed transect and area surveyed as reported in van Zyl *et al.* (2009).

Methodology

Relative Abundance Indices by Zone

For each Zone (Dassen Island, Lambert's Bay, Saldanha Bay and Cape Point) and each leg of the FIMS survey, the computations used to calculate the weighted average CPUE (and its standard error) for each stratum (where stratum here depicts whether a station in a particular Zone is within the 100 m contour (shallow), within the 100 to 200 m contour (deep, applicable to the Cape Point only) or if it lies within a Hotspot) are given below. The various weights applied in these computations are given in van Zyl *et al*. (2009).

The weighted mean Catch Per Unit Effort (CPUE) for each stratum and each leg in a particular Zone is given by:

$$CPUE^{\ell}_{y,z} = \frac{\sum_{i=1}^{z_s} a_i^z C_{y,i}^{\ell,z}}{\sum_{i=1}^{z_s} a_i^z}, \qquad \text{(A5.1)}$$

where

$CPUE^{\ell}_{y,z}$ is the weighted mean CPUE in year y for stratum z and leg ℓ;

$C_{y,i}^{\ell,z}$ is the average number of lobsters caught per trap set at station i in stratum z and year y and leg ℓ;

a_i^z is the area of the transect section within which station i is positioned in stratum z; and

z_s is the number of stations in stratum z.

The sampling standard error of the weighted CPUE for each stratum and each leg in year y is then given by:

$$SE\left(CPUE^{\ell}_{y,z}\right) = \sqrt{\frac{\sigma^2_{y,z,\ell}\sum_{i=1}^{z_s}\left(a_i^z\right)^2}{\left(\sum_{i=1}^{z_s} a_i^z\right)^2}}, \qquad \text{(A5.2)}$$

where

$\sigma^2_{y,z,\ell}$ is the variance of the average number of lobsters caught per trap set at station i in stratum z and year y and leg ℓ ($C_{y,i}^{\ell,z}$), for which the estimate is given by:

$$s^2_{y,z,\ell} = \sum_{i=1}^{z_s}\left(C_{y,i}^{\ell,z} - \overline{C}_y^{\ell,z}\right)^2 \Big/ \left(z_s - 1\right),$$

where $\overline{C}_y^{\ell,z}$ is the unweighted average of the number of lobsters caught per trap set in stratum z and year y and leg ℓ.

The weighted mean CPUE for each stratum in a particular Zone, $CPUE_{y,z}$, is the average of the weighted mean CPUE for each leg. The overall CPUE index for each Zone for all the strata combined is then given by:

$$CPUE_y = \sum_{z=1}^{s} p_z^A CPUE_{y,z} , \tag{A5.3}$$

where the summation is over the *s* strata sampled and

p_z^A is the proportion that the area surveyed in stratum *z* comprises of the total area sampled, i.e. $p_z^A = A_z \Big/ \sum_{z=1}^{s} A_z$, where A_z is the total area sampled in stratum *z*.

The sampling standard error of the overall CPUE index for sampled strata combined is then given by:

$$SE\left(CPUE_y\right) = \sqrt{\sum_{z=1}^{s} \left(p_z^A\right)^2 SE\left(CPUE_{y,z}\right)^2} , \tag{A5.4}$$

where $SE\left(CPUE_{y,z}\right)$ is the standard error of the average of the weighted mean CPUE for each leg. It should be noted that the calculation of the standard errors in this paper has not taken account of any correlation between strata nor of any changes in catchability between the two legs of the survey in a stratum which would invalidate the assumption of independence of samples from leg to leg.

For each Zone, except for Lambert's Bay, CPUE indices were calculated considering each individual Hotspot as a stratum in that Zone. For Lambert's Bay this posed a problem when calculating standard errors of CPUE estimates as most Hotspot strata in this Zone only have one station surveyed in a particular leg and thus no standard deviation can be calculated. Therefore, for Lambert's Bay, it was decided to consider all Hotspot strata as one combined stratum.

In the Cape Point Zone, for the 1997/98 and the 2005/06 seasons, there was only one station in one of the legs and in one of the Hotspot strata. The standard deviation ($\sigma_{y,z,\ell}$) for these two records were estimated as the average of the observed (and computable) standard deviations or CVs for that stratum. The choice between using the average of standard deviations or the average of the CVs was based on which measure was more constant over the years.

The 1999/00 FIMS data point (for Cape Point) is based on only a single leg (leg 2) as the first leg was not conducted.

Comparison with previous FIMS indices

Given the changes in the data and the methodology in obtaining the FIMS indices reported in this paper, a comparison to the previous FIMS indices has been conducted. A comparison between the trends of the new indices to the previous ones is of particular interest as this is the primary information that informs the OMP output. To do this, an exponential curve has been fitted to the FIMS indices over a common period (i.e. 1992/93 to 2006/07). For each Zone the following model has been fitted:

$$\ln\left(CPUE_y\right) = \mu + \alpha\left(year\right), \tag{A5.5}$$

where *year* represents the season in which the survey took place, μ is the intercept and α is the slope.

Results

Table A5.1 reports the FIMS CPUE indices for each individual Zone for rock lobsters measuring more than 60 cm together with their sampling standard errors. Figure A5.1 compares the values reported in Table A5.1 to those obtained previously, as well as a comparison of an exponential curve fitted to each of the series (over the common period of 1992/93 to 2006/07). The trend fits to the old and the new FIMS indices are very similar for all Zones with the exception of Cape Point which shows a more downward trend for the new FIMS indices. Table A5.2 shows the estimate of the slope (and its standard error) for each trend curve fitted, where this slope is effectively the annual proportional change in the index. The more negative trend in the new FIMS series for the Cape Point is the only difference of note (given the precision of the estimates), though the difference is less when the values for the next two years are included.

References

Glazer, J. 2007. GLM analysis applied to the FIMS data. Marine and Coastal Management Document, WG/08/07/WCL16.

van Zyl, D., Auerswald, L. and Merkle, D. 2009. FIMS area calculations, station numbers, category, repeats and position. Marine and Coastal Management Document MCM/2009/JUL/SWG/WCRL/04.

Table A5.0. FIMS data provided by L. Scott (UCT, pers. commn) and used in "OMP-2007 re-cast" (Glazer 2007).

Year	**Zone**			
	Cape Point	**Dassen Island**	**Saldanha Bay**	**Lambert's Bay**
1992/93	125.7	23.2	7.5	3.5
1993/94	187.0	19.3	1.45	0.2
1994/95	116.0	8.2	2.2	0.6
1995/96	130.3	2.6	0.63	8.5
1996/97	94.3	11.2	1.3	18.0
1997/98	112.3	17.4	0.16	0.1
1998/99	137.2	25.6	2.2	5.1
1999/00	103.3			
2000/01	84.43	5.88	0.46	5.25
2001/02	122.63	73.51	0.24	1.11
2002/03	93.27	33.11	0.92	3.27
2003/04	103.84	41.55	0.44	0.89
2004/05	95.47	39.1	0.14	1.01
2005/06	170.74	16.55	0.51	3.12
2006/07	126.6	12.3	0.4	0.4

Table A5.1. FIMS CPUE series for each individual Zone and their corresponding sampling standard errors.

Year	Zone			
	Cape Point	**Dassen Island**	**Saldanha Bay**	**Lambert's Bay**
1992/93	140.75 (17.30)	24.89 (4.370)	2.720 (0.871)	3.228 (1.233)
1993/94	128.18 (13.47)	13.16 (3.435)	0.615 (0.673)	0.137 (0.061)
1994/95	112.43 (20.97)	6.057 (1.730)	0.821 (0.443)	0.204 (0.067)
1995/96	120.07 (17.61)	2.543 (1.196)	0.185 (0.058)	4.341 (1.042)
1996/97	75.50 (9.572)	9.295 (2.733)	0.647 (0.471)	9.855 (2.205)
1997/98	132.26 (19.17)†	12.84 (3.382)	0.106 (0.047)	0.068 (0.046)
1998/99	141.64 (16.32)	22.97 (4.019)	3.403 (0.997)	1.495 (0.571)
1999/00	86.60 (20.02)*			
2000/01	100.71 (16.60)	4.809 (1.119)	0.176 (0.100)	1.344 (0.193)
2001/02	105.01 (18.17)	58.66 (7.127)	0.075 (0.058)	0.214 (0.097)
2002/03	52.02 (10.43)	14.49 (2.623)	0.192 (0.174)	0.473 (0.236)
2003/04	98.67 (14.48)	35.78 (6.696)	0.276 (0.386)	0.420 (0.223)
2004/05	89.05 (12.35)	25.36 (3.935)	0.071 (0.030)	0.375 (0.243)
2005/06	62.71 (35.89)†	15.79 (3.969)	0.241 (0.063)	1.725 (0.722)
2006/07	79.18 (21.90)	13.96 (3.393)	0.119 (0.144)	0.238 (0.098)
2007/08	106.65 (29.10)	21.88 (4.212)	1.267 (1.343)	0.277 (0.193)
2008/09	101.43 (33.20)	9.665(1.974)	0.756 (0.310)	1.207 (0.536)

* Based on only one leg of the survey.
† Standard error based on an estimate because only one station was sampled in a leg for a particular Hotspot.

TABLE A5.2. Trend values (effectively proportional changes per annum) from old and the new FIMS series together with their standard errors.

	Old trend (s.e.) (1992/93 to 2006/07)	**New trend (s.e.) (1992/93 to 2006/07)**	**New trend (s.e.) (1992/93 to 2008/09)**
Cape Point	-0.010 (0.014)	-0.044 (0.014)	-0.028 (0.013)
Dassen Island	0.065 (0.051)	0.063 (0.048)	0.044 (0.038)
Saldanha Bay	-0.156 (0.052)	-0.162 (0.060)	-0.071 (0.059)
Lambert's Bay	-0.019 (0.092)	-0.073 (0.089)	-0.050 (0.070)

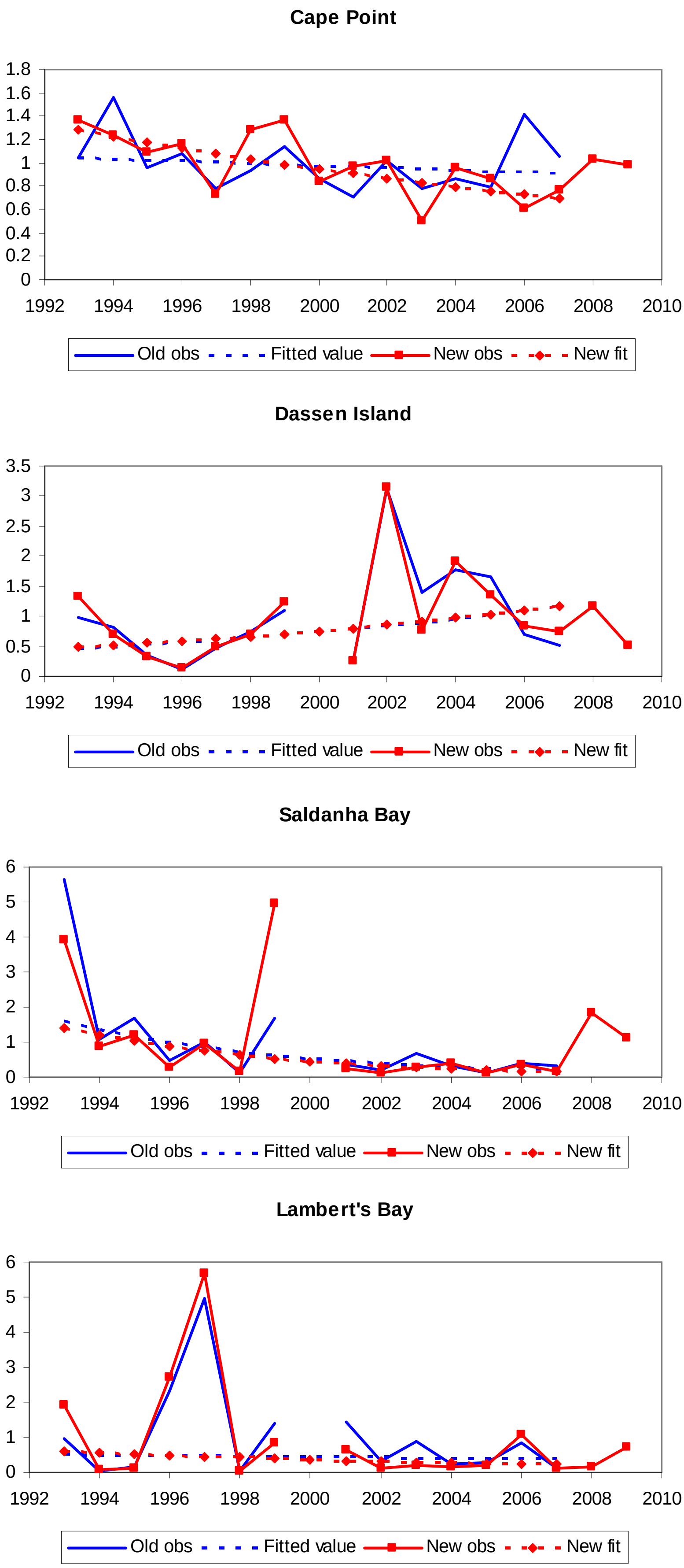

Figure A5.1. Comparison of old and new FIMS CPUE series (normalised to the mean over the 1993–2007 period) as well as the comparison of an exponential trend fitted to each curve. In this plot the period 1993 corresponds to the season 1992/93, and so on.

Appendix 6: Catch data used in the OMP

Table A6.1: Total (all super-areas combined) commercial, recreational, near-shore and interim-relief catch estimates (all in MT).

Season	Commercial	Recreational	Near-shore	Interim relief
1990	2996	441		
1991	2480	455		
1992	2176	469		
1993	2197	391		
1994	1966	336		
1995	1516	379		
1996	1674	496		
1997	1918	340		
1998	1792	249		
1999	2315	360		
2000	1609	404		
2001	2073	468		
2002	2462	583		
2003	2917	320		
2004	3044	320		
2005	2037	320		
2006	3075	300		
2007	1842	257	560	175.06

Data sources

Commercial catches: van Zyl, D. (2008a). West coast rock lobster annual TAC, Catch, Effort and CPUE per Area. MCM document, WG/08/07/WCRL8.

Recreational Estimates: The 1990-2000 estimates were obtained from telephone surveys. The 2001 and 2002 estimates rest on the assumption that the recreational catch will be 20% of the TAC calculated from the OMP for that season. The 2003-2005 estimates are values assumed by the Rock Lobster Scientific Working Group. The 2006 estimate is an *ad hoc* assumption made by management. The 2007 estimate is 10% of the TAC per the OMP rule (see Butterworth, D.S. 2008. Implications of a new survey estimate of the size of the west coast rock lobster recreational catch. MCM/2008/JUL/SWG-WCRL/08). Note that although telephone survey estimates were reported for 2003 to 2007, these were based on a flawed implementation of the methodology concerned (Johnston, S.J. and Butterworth, D.S. 2009. Summary of deliberations by a task group on west coast rock lobster recreational telephone survey catch estimates, and implications of those results. MCM/2009.AUG.SWG/WCRL/13.)

Near shore rights holders quotas: Danie van Zyl (pers. commn).

Interim Relief catch estimates: Keulder and van Zyl. (2008). Interim relief report west coast rock lobster. MCM document, MCM/2008/JUN/SWG-WCRL/03.