OMP 2015 to be used for setting TACs for the West Coast Rock Lobster fishery for the 2015+ seasons

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SUMMARY

This document provides full specifications of OMP 2015 to be used to set allocations for various sectors and super-areas for the 2015+ seasons for the West Coast rock lobster fishery. The management objective remains to increase the male biomass above 75mm CL by at least 35% by 2021 relative to the 2006 level in median terms. This document provides details of the three main components of OMP 2011: 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 the super-areas and different sectors. Further rules allowing for offshore (and nearshore + interim relief/subsistence) tolerance will be developed later.

INTRODUCTION

During 2015 the WCRL SWG reviewed a number of alternate OMP variants for the future management of the west coast rock lobster resource (see FISHERIES/2015/MAY/SWG-WCRL/14, FISHERIES/2015/JUN/SWG-WCRL/15 and FISHERIES/2015/JUL/SWG-WCRL/24).

A final OMP (though with options for possible offshore and nearshore + interim relief/subsistence tolerances being allowed later in the season) was selected by the SWG to put forward to management as the revised OMP 2015. This OMP retains its management target of at least a 35% biomass recovery by 2021, although the projected median B75m(2021/2006) is larger at 1.55 with the lower 5th percentile being 0.99.

OMP 2015 is broadly identical to OMP 2011, but with the following differences.

1) The maximum inter-annual TAC upwards constraint, which applies to both the Global and offshore sectors, has been changed from 10% to 11%.

2) After the initial total offshore TACs by super-area are calculated, a further adjustment is made where 5% of the offshore A8+ TAC is transferred A5+6. This amount transferred from A8+ to A56 has been reduced from its previous value of 10% in order to improve biomass recovery performance in A5+6.
3) Offshore tolerance is allowed as follows: “tolerance” in the offshore allocations later in the season is allowed, such that the offshore allocations in the “best” performing super-area would increase by 10%. This extra allocation would be removed from the super-area with the “worst” performance. Rules for determining the “best” and “worst” super-areas (and when) and the requirements before tolerance can be allowed are specified [to come].
4) Nearshore and interim relief/subsistence tolerance is allowed in a similar manner as for offshore, except that A8+ is EXCLUDED from these tolerance shifts.

AS with OMP 2011, OMP 2015 allows for Exceptional Circumstances to be invoked for a particular super-area which could result in all fishing in that super-area being “suspended” (Low Abundance rule).

The idea underlying the “Low Abundance rule” is not to imply that this complete closure would occur in practice. Rather, what would then need to happen is an early OMP review with shifting of effort by some combination of the nearshore commercial and interim relief/subsistence sectors to other super-areas. The reason underlying the presentation of calculation results in this extreme form is to demonstrate that if the situation became “so bad” in a super-area, it remains possible to achieve some reasonable extent of recovery by appreciable reductions in future catches from that super-area.

Appendix 6 details the general Exceptional Circumstances rules with specific entries as pertain to the west coast rock lobster.

DESCRIPTION OF OMP 2015

1) The combination of data across super-areas

The OMP uses input data from all five super-areas where the data type concerned has been available in the past and is anticipated to continue being available in the future.

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 2009[1]…*Y*-1.

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

$$CPUE_Y^{trap,A1-2} \Rightarrow X_Y^{trap,A1-2} = \frac{CPUE_Y^{trap,A1-2}}{Geometric\ mean\ (CPUE_y^{trap,A1-2}:\ y = 2009...2013)} \qquad (1)$$

STEP 4: Calculate a combined CPUE (and FIMS) index as follows (here trap CPUE is used as an example):

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

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

The weights have been calculated in the following manner. For trap and hoop CPUE for example, obtain $\overline{B}^{75}$, the average (male plus female) biomass above 75mm carapace length over the **2006-2014**[2] period for each super-area from the reference case operating model (Johnston 2015):

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

then:

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[1] Was 2005 for OMP 2011

[2] Was 2000-2009 for OMP 2011

$$\overline{B}^{75}_{TOTAL} = \sum_{A=1..8} \overline{B}^{75}_{A} \text{ and} \tag{3}$$

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

For FIMS, the procedure is as above, but $\overline{B}^{60}$ is used instead of $\overline{B}^{75}$.

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

Table 1 below lists the resultant weighting *w* values. (Note that '-' 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.)

Table 1: The weighting (*w*) values for each gear and super-area, when combining abundance indices over super-areas.

	w^{trap}_{A}	w^{hoop}_{A}	w^{FIMS}_{A}
A1-2	-	0.087	-
A3-4	-	0.213	0.153
A5-6	-	0.172	0.109
A7	0.339	-	0.074
A8	0.661	0.528	0.663

Note: If there is a data value missing for a particular super-area in season *y* (for example tagging does not take place), then the average of the values for the $y-1$ and $y+1$ seasons values is to be used in its place. If the data value is missing for the most recent year, then the value for the preceding year is used.

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 2015).

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 – see Table 2). Note also that that here the biomass relates to total male biomass above 70mm only.

Thus $\beta_y = w_{A1-2}^{SG}\beta_y^{A1-2} + w_{A3-4}^{SG}\beta_y^{A3-4} + w_{A5-6}^{SG}\beta_y^{A5-6} + w_{A7}^{SG}\beta_y^{A7} + w_{A8}^{SG}\beta_y^{A8}$ (4)

where

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

Table 2: The weighting (*w*) values for each super-area, when combining somatic growth over super-areas.

	w_A^{SG}
A1-2	0.032
A3-4	0.175
A5-6	0.128
A7	0.140
A8	0.524

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 (and equally very low) 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 five super-areas). Thus any value which is greater then 3.0 times the geometric average of the previous five years' values is capped at that average value multiplied by 3.0. This capped value continues to be used in the future. Similarly, any value which is less than 0.33 of this average is capped at that 33% level.

2. Method for calculating the global TAC

First, an initial global TAC is computed as:

$$TAC_y^{G,1} = \alpha\left(\bar{J}_y - J_{min}\right) \tag{5}$$

where

α and J_{min} are two tuning parameters, and

$\bar{J}_y$ is the combined abundance index – combined over both super-areas and gear-types:

$$\bar{J}_y = \sum_{gear=1}^{3} W^{gear} J_y^{gear} \tag{6}$$

where

J_y^{gear} is a relative measure of the immediate past level (2009-2013)[3] in the abundance index "gear" (I_y^{gear}- see equation (2), for gear type trap, hoop or FIMS) as available for use in calculation of the global TAC for year *y:*

$$J_y^{gear} = \frac{e^{\left[\sum_{y'=y-3}^{y'=y-1} \ln\left(I_{y'}^{gear}\right)\right]/3}}{e^{\left[\sum_{y'=2009}^{y'=2013} \ln\left(I_{y'}^{gear}\right)\right]/5}} \tag{7}$$

and

W^{gear} is the relative weight given to that gear type.

The W^{gear} values selected by the SWG are:

$W^{trap} = 0.45$; $W^{hoop} = 0.35$; and $W^{FIMS} = 0.20$.

The basis for these choices was the inverse of the variance of the assessment model residuals for each index, which the SWG then modified to reflect a more even allocation of weights.

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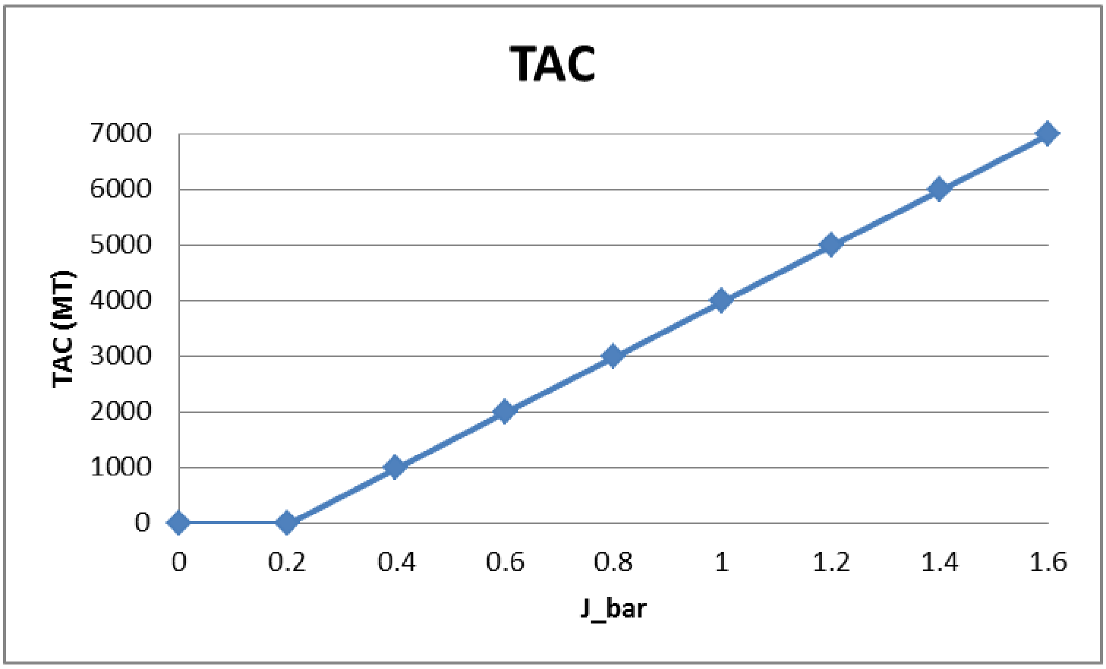
[3] OMP 2011 used 2005-2009

For OMP 2015, α=5000 and J_{min}=0.2 were set to achieve the agreed recovery target (see Figure 1).

Figure 1: The figure below shows the initial global TAC as a function of the combined abundance index $\bar{J}$ (shown below as **J_bar**), for the OMP where the value of α is 5000 and $J_{\min}$ is 0.2 in equation (5).



Adjusting TAC for recent somatic growth

The initial global TAC value from equation (5) is then adjusted up or down by the addition (which could be a subtraction) of an amount "Z" such that:

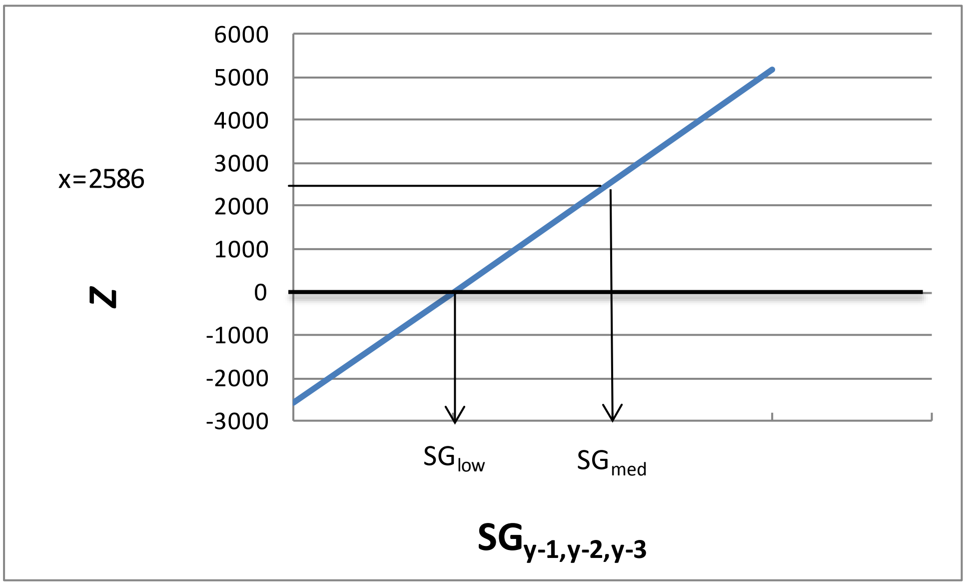
$$TAC_y^{G,2} = TAC_y^{G,1} + Z \qquad (8)$$

where

$$Z = \bar{x}\frac{SG_{y-1,y-2,y-3} - SG_{low}}{SG_{med} - SG_{low}} \qquad (9)$$

where $SG_{y-1,y-2,y-3}$ is the geometric mean of the combined somatic growth index for the three most recent seasons. The value of $\bar{x}$, which is 2586 MT, was calculated in 2011 by comparing the tonnage differentials between the low and medium somatic growth rates that would result in the same male biomass level for the resource as a whole after 10 years, i.e. by 2021 in terms of the reference case operating model. Figure 2 below illustrates the dependence of *Z* on future values of $SG_{y-1,y-2,y-3}$.

Figure 2: The relationship between Z and future values of $SG_{y-1,y-2,y-3}$ (see Equation 9).



If $SG_{y-1,y-2,y-3}$ is equal to $\mathrm{SG}_{\mathrm{low}}$, then the value of Z will be zero. If the value of $SG_{y-1,y-2,y-3}$ is equal to $\mathrm{SG}_{\mathrm{med}}$, then the value of Z will be 2586 MT. If $SG_{y-1,y-2,y-3}$ drops below $\mathrm{SG}_{\mathrm{low}}$, then the value of Z will be negative, and the TAC will be adjusted downwards.

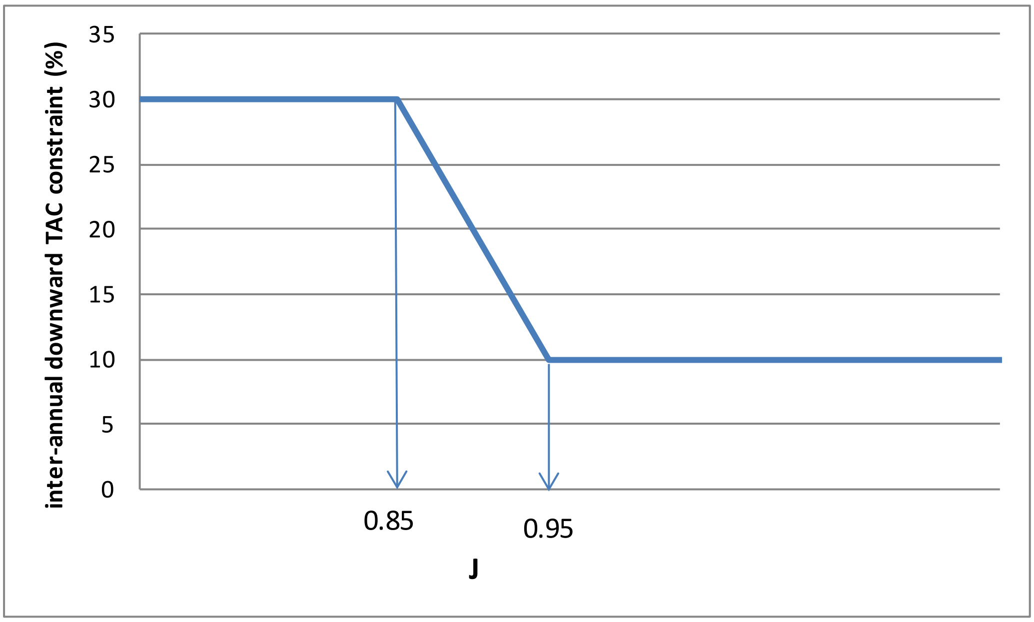
Inter-annual TAC constraints

Both the global TAC and total Offshore TAC values are constrained by the amount they can vary from the previous year's value. This amount has been set at 10% for TAC reductions and a maximum of 11% for TAC annual increases. However, a further rule, "RULE 1", allows for the TAC values to decrease by as much as 30% under certain conditions of poor resource performance, as indexed by $\bar{J}_y$. Figure 3 below shows how this TAC decrease constraint will be set. The amount of TAC decrease permitted is dependent on the $\bar{J}_y$ value and is set equal to 10% for values of $\bar{J}_y > 0.95$ and to 30% for values of $\bar{J}_y < 0.85$, with linear interpolation for $\bar{J}_y$ values between 0.85 and 0.95.

Following implementation of these constraints, the global TAC calculated may change:

$$TAC_y^{G,2} \rightarrow TAC_y^{G,3}$$

Figure 3: RULE 1 - inter-annual downward TAC constraint calculation based on value of $\bar{J}$ (shown below as **J**).



3. Method for calculating the sector splits of the global TAC

The global TAC is split into allocations to the different sectors using what was agreed at the April 8 2015 joint SWH/Management meeting (see and Table 3 of FISHERIES/2015/MAR/SWG-WCRL/10).

Recreational Allocation

$$TAC_y^{REC} = TAC_{y-1}^{REC} \tag{10}$$

$$if\ \ \frac{TAC_y^{REC}}{TAC_y^{G,3}} < 0.03 \quad \text{then} \quad TAC_y^{REC} = 0.0384\, TAC_y^{G,3} \tag{11}$$

$$if\ \ \frac{TAC_y^{REC}}{TAC_y^{G,3}} > 0.05 \quad \text{then} \quad TAC_y^{REC} = 0.0384\, TAC_y^{G,3} \tag{12}$$

$$if\ \ TAC_y^{REC} > 400\ MT \quad \text{then} \quad TAC_y^{REC} = 400\ MT \tag{13}$$

Interim relief/Subsistence allocation

$$TAC_y^{IR} = TAC_{y-1}^{IR} \tag{14}$$

$$if \ \ \frac{TAC_y^{IR}}{TAC_y^{G,3}} < 0.10 \quad \text{then} \quad TAC_y^{REC} = 0.1307\, TAC_y^{G,3} \tag{15}$$

$$if \ \ \frac{TAC_y^{IR}}{TAC_y^{G,3}} > 0.16 \quad \text{then} \quad TAC_y^{REC} = 0.1307\, TAC_y^{G,3} \tag{16}$$

$$if \ \ TAC_y^{IR} > 600\, MT \quad \text{then} \quad TAC_y^{IR} = 600\, MT \tag{17}$$

Nearshore commercial allocation

$$TAC_y^{Nearshore} = TAC_{y-1}^{Nearshore} \tag{18}$$

$$if \ \ \frac{TAC_y^{Nearshore}}{TAC_y^{G,3}} < 0.17 \quad \text{then} \quad TAC_y^{Nearshore} = 0.2088\, TAC_y^{G,3} \tag{19}$$

$$if \ \ \frac{TAC_y^{Nearhsore}}{TAC_y^{G,3}} > 0.25 \quad \text{then} \quad TAC_y^{Nearshore} = 0.2088\, TAC_y^{G,3} \tag{20}$$

$$if \ \ TAC_y^{Nearshore} > 800\, MT \quad \text{then} \quad TAC_y^{Nearshore} = 800\, MT \tag{21}$$

Offshore commercial allocation

$$TAC_y^{Offshore} = TAC_y^{G,3} - TAC_y^{REC} - TAC_y^{IR} - TAC_y^{Nearshore} \tag{22}$$

$$if\ TAC_y^{Offshore} > 1.11\ TAC_{y-1}^{Offshore} \ \ \text{then}\ TAC_y^{Offshore} = 1.11\, TAC_{y-1}^{Offshore} \tag{23}$$

As for the global TAC downward constraint “RULE 1” applies, i.e. “RULE 1”, allows for the $TAC_y^{Offshore}$ value to decrease by as much as 30% under certain conditions of poor resource performances, as indexed by $\bar{J}_y$. Figure 3 above shows how this TAC decrease constraint will be set. The amount of TAC decrease permitted is dependent of the $\bar{J}_y$ value and is set equal to 10% for values of $\bar{J}_y > 0.95$ and to 30% for values of $\bar{J}_y < 0.85$, with linear interpolation for $\bar{J}_y$ values between 0.85 and 0.95.

Final global TAC

$$TAC_y^{G,final} = TAC_y^{REC} + TAC_y^{IR} + TAC_y^{Nearshore} + TAC_y^{Offshore} \qquad (24)$$

Note that this means that the final global TAC may change by more than 10% from the previous year's value.

In the event of a change to the allocation to the Interim relief/Subsistence, Nearshore commercial or Offshore commercial sector, the quota to each rights holder in that sector will be adjusted by the same proportion as the allocation to that whole sector has been adjusted.

For the Recreational sector, the adjustment will be effected by changing the duration of the season by the same proportion as the allocation is changed, starting from a baseline of 80 days for the 2007-2009 allocations each of 257 tons. This will be kept under review in the light of telephone survey and permit sale records, and adjusted if necessary in proportion to changes in these.

Note that no upward adjustment will be considered to sector allocations should that sector undercatch its allocation for the preceding season. The undercatch will be considered as a desirable contribution to an improved recovery rate, and rights holders will in due course benefit through a consequent improvement in the $\bar{J}$ combined abundance index upon which the TAC depends. Should a sector allocation be overcaught by a non-trivial amount, the situation will be dealt with under Appendix 6 of general Exceptional Circumstances provisions.

Tolerance in offshore sector

Tolerance in the offshore allocations will be considered later in the season, such that the offshore allocations in the "best" performing super-area could increase by a maximum of 10% (only once X% of the allocation has been caught in that super-area). This extra allocation would be removed from the super-area with the "worst" performance. The offshore TAC shift due to "tolerance" would not be expected to be requested each year, and the full amount of the requested offshore TAC shift may be less than the maximum 10%. This is if the poorly performing super-area from which the offshore TAC is to be shifted, has already had sufficient offshore TAC caught by the time of the request, and therefore there is simply not enough remaining TAC from that super-area to fulfil the request. The offshore tolerance could theoretically be between any of A3+4, A5+6, A7 and A8+. [The exact rules to determine if, when and how much offshore tolerance will be allowed will be developed later in 2015.]

Tolerance in nearshore + interim relief/subsistence sectors

Tolerance in the nearshore and interim relief/subsistence sectors will also be considered later in the season, along the lines of described above for the offshore sector. However, the nearshore and interim relief/subsistence tolerance will only be considered between any of A1+2, A3+4, A5+6 (i.e. A8+ is excluded from nearshore and interim relief/subsistence tolerance). [The exact rules to determine if, when and how much nearshore and interim relief/subsistence tolerance will be allowed will be developed later in 2015.

Table 3: Agreed sector splits of global TAC for the revised OMP.

Sector	2014/15 TAC	Baseline % of global TAC	Range of global TAC allowed before revert to baseline	Maximum allowed
Recreational	69.20	3.84%	3% - 5%	400
Interim relief/ Subsistence	235.30	13.07%	10% - 16%	600
Nearshore commercial	376.10	20.88%	17% - 25%	800
Offshore commercial	1120.25	62.21%	max increase 11% pa min decrease 10-30% pa (RULE 1)	

For the 2016 season, with the presumed removal of Exceptional Circumstances provisions for Super-Area 7, the catch allowed there will likely increase above the 80 MT currently allowed. This increased catch will be shared amongst sectors in accordance with the Baseline % splits in Table 3.

4. Method for splitting the sector allocations amongst super-areas

For each sector, the catch allocation needs to be split amongst the five super-areas. Table 4 below provides the proportions to be used to achieve these splits (which correspond to the proportions agreed for the OMP testing). The splitting of the Offshore allocation is described below.

In practice, recreational permit allocation/usage cannot be restricted on a super-area basis, but ongoing annual telephone surveys will be used to monitor these proportions and how they change. If the change is substantial, implementation of general Exceptional Circumstance provisions will be considered.

If one duplicates the 2014 season sector allocations amongst super-areas for the future, these splits would be as shown in Table 4. The re-allocation of the recreational catch from A8+ to A7 in 2016 compared to 2015 is as per previous decision of the SWG.

Table 4: Agreed super-area splits of the Nearshore, Subsistence and Recreational allocations for the 2015+ seasons.

	Neashore		**Subsistence**		**Recreational**	
	2015	**2016+**	**2015**	**2016+**	**2015**	**2016+**
A1+2	0.064	0.064	0.057	0.057	0.024	0.024
A3+4	0.175	0.175	0.177	0.177	0.135	0.135
A5+6	0.007	0.007	0.192	0.192	0.135	0.135
A7	0.000	0.040	0.000	0.040	0.000	0.040
A8+	0.685	0.645	0.574	0.534	0.706	0.666

Splitting of Offshore Allocation

The Offshore allocation is split between the super-areas based on a method (as used for OMP 2007 recast) that uses the slopes of the recent resource indices, e.g. trap and hoop CPUE and FIMS where available. The Offshore allocation is split between A3+4, A5+6, 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 with data, and calculate the slope. Note that as A56 trap series only recently re-started in 2010, A56 trap data are excluded from the combined data for A56 – i.e. this is based on hoops and FIMS only.

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:

$$slope^A = \frac{\left(\frac{slope^A_{trap}}{\sigma^2_{slope^A_{trap}}} + \frac{slope^A_{hoop}}{\sigma^2_{slope^A_{hoop}}} + \frac{slope^A_{FIMS}}{\sigma^2_{slope^A_{FIMS}}}\right)}{\frac{1}{\sigma^2_{slope^A_{trap}}} + \frac{1}{\sigma^2_{slope^A_{hoop}}} + \frac{1}{\sigma^2_{slope^A_{FIMS}}}} \quad \text{(assuming three series),} \qquad (25)$$

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 allocation (TAC_y^{off}). If the allocations do not total to the total Offshore commercial allocation, simply scale them all by the same proportion so that they do total to match this required allocation.

Note: For the 2015 season, a fixed amount of 80 MT for Offshore for Area 7 will be allocated (due to expected Exceptional Circumstances) and Step 4 above used to split the remaining Offshore TAC between A3+4, A5+6 and A8+. For 2016+, where it is assumed at this time that Exceptional Circumstance will not apply for Area 7, STEP 4 above will be applied for splitting the Offshore TAC amongst A3+4, A5+6, A7 and A8+.

STEP 5: A 5% amount of A8+ offshore TAC is shifted from A8+ to A56.

5. Low Abundance rule

$J_{\mathrm{area},y}$ is an index of recent resource performance for that super-area, relative to recent (**2009-2013**[4]) levels, which is calculated for each super-area using the resource indices available for that super-area. The equations used for calculating $J_{\mathrm{area},y}$ are given below.

If $J_{area,y} < X_{crit}^{area}$ then Exceptional Circumstances are invoked for that super-area and year (*y*). Evaluations will then be carried out by the Working Group which

a) will ensure that catches in the super-area concerned are set appreciably lower than would have been the case under the OMP; and
b) will examine whether any of the catch left from that super-area can be safely transferred to other super-areas until the time of the next OMP review.

The values of X_{crit}^{area} to be used are:

X_{crit}^{A1+2} =0.7

X_{crit}^{A3+4} =0.85

X_{crit}^{A5+6} =0.7

X_{crit}^{A7} =0.8

X_{crit}^{A8+} =0.7

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[4] Was 2005-2009 for OMP 2011

Method used for calculating $J_{area,y}$ values for input to the Low Abundance rule

The EC rule requires a single index for each super-area using the available trap CPUE, hoop CPUE and FIMS for each season in the future.

STEP 1: For each super-area for which data are assumed to be available in the future, there will be for each 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 used as an example) over the year period 2009…2013.

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

$$CPUE_Y^{trap,A1-2} \Rightarrow X_Y^{trap,A1-2} = \frac{CPUE_Y^{trap,A1-2}}{Geometric\ mean\ (CPUE_y^{trap,A1-2}:\ y = 2009...2013)} \tag{26}$$

STEP 4: Calculate a combined index for each area as follows (including only the pertinent indices):

$$J^*_{area,Y} = (w^{trap}_{area} X_Y^{trap,area} + w^{hoop}_{area} X_Y^{hoop,area} + w^{FIMS}_{area} X_Y^{FIMS,area}) / (w^{trap}_{area} + w^{hoop}_{area} + w^{FIMS}_{area}) \tag{27}$$

where the weights are as given in Table 1a.

Finally, $J_{area,Y}$ is calculated as the geometric mean of the three most recent years:

$$J_{area,Y} = e^{[\sum_{T=Y-1}^{T=Y-3} \ln(J^*_{area,T})]/3} \tag{28}$$

References

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Appendix 1: 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 A1.1.

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:

$$y(t) = \begin{cases} \text{int}(t), \text{ if } t - \text{int}(t) \leq 0.25 \\ \text{int}(t)+1, \text{ if } t - \text{int}(t) > 0.25 \end{cases} \qquad \text{(A1.1)}$$

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

The moult season of release and recapture are defined as:

$$\begin{aligned} y_i^- &= y(t_i^-) \\ y_i^+ &= y(t_i^+) \end{aligned} \qquad \text{(A1.2)}$$

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 $y+\overline{x}_m$ and standard deviation δ_m, truncated at the beginning and end of the season. The parameters $\overline{x}_m$ 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:

$$pmoult(A) = pm(m_i^-)\,pm(m_i^+) \qquad \text{(A1.3)}$$

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

$$pmoult(B) = (1 - pm(m_i^-))(1 - pm(m_i^+)) \tag{A1.4}$$

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

$$pmoult(C) = pm(m_i^-)(1 - pm(m_i^+)) . \tag{A1.5}$$

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

$$pmoult(D) = (1 - pm(m_i^-))pm(m_i^+) \tag{A1.6}$$

It is easily verified that $pmoult(A) + pmoult(B) + pmoult(C) + pmoult(D) = 1$ (A1.7)

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:

$$pmoult(A) = pm(m_i^-) \tag{A1.8}$$

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

$$pmoult(B) = 1 - pm(m_i^-) \tag{A1.9}$$

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

$$pmoult(C) = 0 \tag{A1.10}$$

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

$$pmoult(D) = 0 . \tag{A1.11}$$

4.3 The growth model for a single moult.

$$\hat{g}_i(m) = A(a_i) + M(m) + \rho l_i^-(m) + r(a_i,m) + \mu + \varepsilon_i + \zeta_i = \hat{g}_i(m,a_i,l_i^-(m)) + \varepsilon_i(m) + \zeta_i \tag{A1.12}$$

where:

$A(a_i)$	is an area factor for sub-area *a*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*):

$$l_i^-(m+1) = l_i^-(m) + \hat{g}_i(m, a_i, l_i^-(m)) + \varepsilon_i(m) \qquad \text{(A1.13)}$$

Successive increments in growth are represented as follows:

$$l_i^-(m+2) = l_i^-(m+1) + \hat{g}_i(m+1, a_i, l_i^-(m+1)) + \varepsilon_i(m+1) \qquad \text{(A1.14)}$$

which can be rewritten as:

$$\begin{aligned} l_i^-(m+2) = {} & [l_i^-(m) + \hat{g}_i(m, a_i, l_i^-(m)) + \varepsilon_i(m)] + \hat{g}_i(m+1, a_i, [l_i^-(m) + \\ & \hat{g}_i(m, a_i, l_i^-(m)) + \varepsilon_i(m)]) + \varepsilon_i(m+1) \end{aligned} \qquad \text{(A1.15)}$$

The latter simplifies to:

$$\begin{aligned} l_i^-(m+2) = {} & [l_i^-(m) + \hat{g}_i(m, a_i, l_i^-(m))] + \hat{g}_i(m+1, a_i, [l_i^-(m) + \\ & \hat{g}_i(m, a_i, l_i^-(m))]) + \varepsilon_i(m+1) + (1 + \rho\varepsilon_i(m)) \end{aligned} \qquad \text{(A1.16)}$$

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

$$\begin{aligned} l_i^-(m+2) - l_i^-(m) & = [\hat{g}_i(m, a_i, l_i^-(m))] + \hat{g}_i(m+1, a_i, [l_i^-(m) + \\ & \quad \hat{g}_i(m, a_i, l_i^-(m))]) + \varepsilon_i(m+1) + (1 + \rho\varepsilon_i(m)) \\ & = \hat{G}_i + \varepsilon_i(m+1) + (1 + \rho\varepsilon_i(m)) \end{aligned} \qquad \text{(A1.17)}$$

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:

$$Var(G_i(3))=\sigma_g^2+[1+\rho]\sigma_g^2+[1+\rho][1+\rho]\sigma_g^2+\sigma_m^2 \qquad \text{(A1.18)}$$

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

$$Var(G_i(n))=\left(\sum_{r=0}^{n-1}\sigma_g^2[1+\rho]^{2r}\right)+\sigma_m^2 \qquad \text{(A1.19)}$$

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: $$\frac{pmoult(D)e^{\frac{-(G_i-\hat{G}_i(D))^2}{2Var(G_i(D))}}}{\sqrt{Var(G_i(D))}}. \qquad \text{(A1.20)}$$

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

$$p(G_i) \propto \frac{pmoult(A)e^{\frac{-(G_i-\hat{G}_i(A))^2}{2Var(G_i(A))}}}{\sqrt{Var(G_i(A))}} + \frac{pmoult(B)e^{\frac{-(G_i-\hat{G}_i(B))^2}{2Var(G_i(B))}}}{\sqrt{Var(G_i(B))}} + \frac{pmoult(C)e^{\frac{-(G_i-\hat{G}_i(C))^2}{2Var(G_i(C))}}}{\sqrt{Var(G_i(C))}} + \frac{pmoult(D)e^{\frac{-(G_i-\hat{G}_i(D))^2}{2Var(G_i(D))}}}{\sqrt{Var(G_i(D))}} \qquad \text{(A1.21)}$$

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

$$LF \propto \prod_{i=1}^{N} \left[\frac{pmoult(A)e^{\frac{-(G_i-\hat{G}_i(A))^2}{2Var(G_i(A))}}}{\sqrt{Var(G_i(A))}} + \frac{pmoult(B)e^{\frac{-(G_i-\hat{G}_i(B))^2}{2Var(G_i(B))}}}{\sqrt{Var(G_i(B))}} + \frac{pmoult(C)e^{\frac{-(G_i-\hat{G}_i(C))^2}{2Var(G_i(C))}}}{\sqrt{Var(G_i(C))}} + \frac{pmoult(D)e^{\frac{-(G_i-\hat{G}_i(D))^2}{2Var(G_i(D))}}}{\sqrt{Var(G_i(D))}} \right] \qquad \text{(A1.22)}$$

The objective function is then given by:

$$F = -\ln(LF) + d\ln(\phi) + \sum_a \sum_m \frac{[r(a,m)]^2}{2\phi^2} \qquad \text{(A1.23)}$$

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:

$$\hat{g}_{70}(m) = \mu + \overline{A} + M(m) + \rho.70 \qquad \text{(A1.24)}$$

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 A1.12.

The spatially disaggregated estimates are obtained as follows:

- For Area 8 – 14 (Cape) i.e A8+*: 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) i.e. A3+4*: using Model 1, standardized using the median area factor for sub-areas within this zone.
- For Area 5 – 6 (West2) i.e. A5+6*: using Model 1, standardized using the median area factor for sub-areas within this zone.
- For Area 7 (Dassen) i.e. A7*: 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) i.e. A1+2*: 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.

The estimates marked * are used in the OMP calculations.

Table A1.1 Area classification.

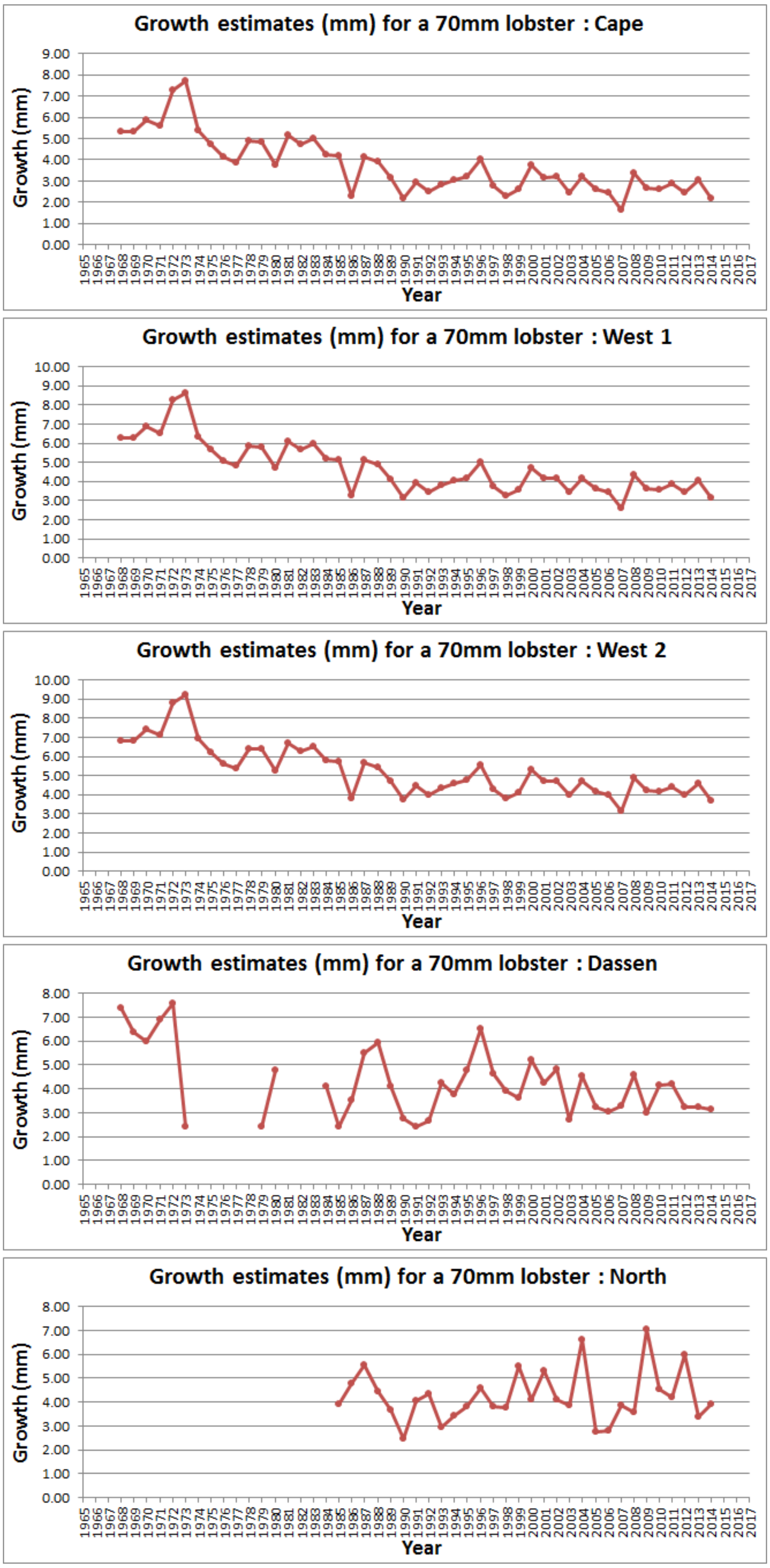
Super-Area	Macro-Area	Area	Sub-Area
NORTH	Port Nolloth	Area 1	**PN2**
		Area 1	**PN3**
		Area 1	**PN4**
		Area 1	**PN5**
		Area 1	**PN6**
	Hondeklip Bay	Area 2	**HKB**
WEST 1	Elands Bay	Area 3	**EB**
	Lamberts Bay	Area 4	**LB1**
		Area 4	**LB2**
		Area 4	**LB3**
		Area 4	**LB4**
		Area 4	**LB5**
WEST 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**

Table A1.2. Growth estimates in mm (with standard errors) for a 70mm lobster in each of the 5 super-areas.

Year	MODEL 1						MODEL 2b		MODEL 3b	
	CAPE		WEST 1		WEST 2		DASSEN		NORTH	
	Areas 8 to 14		Areas 3 & 4		Areas 5 & 6		Area 7		Areas 1 & 2	
1968	5.3139	(0.24459)	6.2809	(0.2917)	6.8376	(0.3487)	7.4031	(0.18249)	**	
1969	5.3168	(0.22891)	6.2838	(0.27636)	6.8404	(0.33628)	6.3503	(0.10236)	**	
1970	5.8819	(0.26515)	6.849	(0.31454)	7.4056	(0.3675)	6.0056	(0.11063)	**	
1971	5.5799	(0.2621)	6.5469	(0.30909)	7.1036	(0.36375)	6.8765	(0.13422)	**	
1972	7.2804	(0.38734)	8.2474	(0.4272)	8.8041	(0.48027)	7.5802	(0.4956)	**	
1973	7.6824	(0.56417)	8.6495	(0.59733)	9.2061	(0.58627)	2.4031	(0.18299)	**	
1974	5.3998	(0.60333)	6.3668	(0.62164)	6.9235	(0.56404)	**		**	
1975	4.7193	(0.32813)	5.6864	(0.27669)	6.243	(0.39052)	**		**	
1976	4.1088	(0.37447)	5.0759	(0.32062)	5.6325	(0.43062)	**		**	
1977	3.8495	(0.63671)	4.8165	(0.61844)	5.3732	(0.67044)	**		**	
1978	4.8905	(0.30642)	5.8575	(0.31011)	6.4142	(0.30601)	**		**	
1979	4.8467	(0.30893)	5.8137	(0.3228)	6.3704	(0.27559)	2.4031	(0.18522)	**	
1980	3.7395	(0.45952)	4.7066	(0.47379)	5.2632	(0.5122)	4.7662	(0.071413)	**	
1981	5.1475	(0.27574)	6.1145	(0.29068)	6.6712	(0.25936)	**		**	
1982	4.7306	(0.2245)	5.6976	(0.26657)	6.2542	(0.32206)	**		**	
1983	5.0192	(0.31367)	5.9863	(0.29623)	6.5429	(0.37602)	**		**	
1984	4.2466	(0.2997)	5.2136	(0.28149)	5.7703	(0.37)	4.1244	(0.35683)	**	
1985	4.1885	(0.31293)	5.1555	(0.30931)	5.7122	(0.38184)	2.4031	(0.18307)	3.9102	(0.37315)
1986	2.3089	(0.30874)	3.276	(0.325)	3.8326	(0.37924)	3.5057	(2.0911)	4.7566	(0.36137)
1987	4.1525	(0.24679)	5.1195	(0.25759)	5.6762	(0.32569)	5.517	(0.22349)	5.5473	(0.35927)
1988	3.9223	(0.25003)	4.8893	(0.26053)	5.446	(0.32951)	5.9161	(0.21241)	4.4248	(0.38245)
1989	3.1656	(0.26135)	4.1327	(0.27303)	4.6893	(0.33822)	4.1243	(0.21928)	3.6649	(0.67684)
1990	2.1961	(0.23526)	3.1631	(0.26337)	3.7198	(0.33244)	2.7786	(0.29048)	2.4693	(0.61119)
1991	2.9329	(0.23466)	3.8999	(0.26231)	4.4566	(0.33122)	2.4031	(0.18249)	4.0749	(0.47159)
1992	2.4867	(0.21856)	3.4538	(0.24194)	4.0104	(0.30733)	2.6425	(0.15456)	4.3326	(0.53968)
1993	2.845	(0.24972)	3.8121	(0.27437)	4.3687	(0.32535)	4.227	(0.17297)	2.9649	(0.46398)
1994	3.0647	(0.26241)	4.0317	(0.28401)	4.5884	(0.34233)	3.7478	(0.13186)	3.4287	(0.54755)
1995	3.2249	(0.2565)	4.1919	(0.27666)	4.7486	(0.3317)	4.7715	(0.16785)	3.8166	(0.54495)
1996	4.0392	(0.26154)	5.0062	(0.28146)	5.5629	(0.33536)	6.5123	(0.24856)	4.5877	(0.56149)
1997	2.7627	(0.26101)	3.7298	(0.281)	4.2864	(0.33618)	4.6268	(0.18481)	3.8262	(0.56911)
1998	2.2887	(0.27065)	3.2557	(0.2912)	3.8124	(0.34988)	3.914	(0.12687)	3.774	(0.64713)
1999	2.5959	(0.26671)	3.563	(0.28713)	4.1196	(0.34274)	3.6017	(0.12953)	5.4899	(0.93681)
2000	3.7716	(0.29159)	4.7386	(0.31141)	5.2953	(0.36658)	5.2328	(0.19102)	4.126	(0.5633)
2001	3.1814	(0.25963)	4.1485	(0.28055)	4.7051	(0.34183)	4.2288	(0.1697)	5.3103	(0.60932)
2002	3.2065	(0.27341)	4.1735	(0.29454)	4.7301	(0.35323)	4.8366	(0.20151)	4.1013	(0.56561)
2003	2.4624	(0.26429)	3.4294	(0.28492)	3.9861	(0.34524)	2.6972	(0.18962)	3.8488	(0.55565)
2004	3.2133	(0.27069)	4.1803	(0.29156)	4.737	(0.3507)	4.5447	(0.31119)	6.6004	(0.66946)
2005	2.6328	(0.27699)	3.5998	(0.29825)	4.1564	(0.3563)	3.2494	(0.16435)	2.7529	(0.51109)
2006	2.4544	(0.265)	3.4214	(0.28948)	3.978	(0.34873)	3.0459	(0.15607)	2.8152	(0.50145)
2007	1.6243	(0.2578)	2.5914	(0.28768)	3.148	(0.34681)	3.3052	(0.14629)	3.8798	(0.56688)
2008	3.3885	(0.26151)	4.3555	(0.28469)	4.9122	(0.34484)	4.6046	(0.20979)	3.5841	(0.56199)
2009	2.6892	(0.26825)	3.6563	(0.28961)	4.2129	(0.34908)	2.9831	(0.10777)	7.0231	(0.73265)
2010	2.6201	(0.25938)	3.5872	(0.28117)	4.1438	(0.34205)	4.1503	(0.13602)	4.5342	(0.55673)
2011	2.8851	(0.25558)	3.8522	(0.28102)	4.4088	(0.34173)	4.2196	(0.084591)	4.1973	(0.58608)
2012	2.4653	(0.25888)	3.4323	(0.28502)	3.989	(0.34481)	3.2404	(0.12177)	5.9945	(0.82901)
2013	3.0603	(0.29153)	4.0273	(0.31359)	4.584	(0.36869)	3.2426	(0.48664)	3.3837	(1.3966)
2014	2.1847	(0.24751)	3.1517	(0.26155)	3.7084	(0.33333)	3.1457	(0.48092)	3.9102	(0.37315)
Rho				**-0.073986**	**(0.0015993)**				**-0.076320**	**(0.0056715)**

*** Indeterminate due to lack of data.*

Figure A1. Comparison of standardized growth rate estimates for 70 mm lobsters in each of the 5 super-areas.



Appendix 2: 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 Area 3+4 and Area 7, while a Generalized Linear Mixed Model (GLMM) has been applied to Area 8+, which includes Areas 8, 10 and 11.

Basic data

The past trapboat dataset covers the period 1981-2014, the 2014 data being partial since at the time the analyses were conducted the fishing season was still underway. More refined data, detailing catches at a sub-area level, are only available since 1992.

Tables A2.1-2.5 indicate the sample sizes per season and month for Areas 3+4, 7 and 8+ respectively. The shaded areas indicate the data which were considered in the analyses, with the lighter portion of the shaded area for Area 3+4 and Area 7 indicating the core information contributing to the final index of abundance. 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 2A.

The models

The models applied to the data from each area are shown in Table A2.6. Diagnostic tests related to the studentized residuals obtained from each of the models 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 ±1 standard deviations for Area 3+4 and ±2 standard deviations for Areas 7 and 8+ respectively.

The equations applied to obtain the area-specific standardized CPUE indices are shown in Table A2.7. Given that the 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. The sizes of Area 3 and 4 are shown in Table A2.8.

Interpolation was used to fill empty interaction cells where applicable. This involved taking the average of the $\ell n\widehat{CPUE}_{seas,m}$ 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	**January**	**February**	**March**
1993		X	

1994	X	Empty Cell	X
1995		X	

It should be noted that although fishing took place in 2008 in Area 3+4, this season has not been included in the analyses since it is evident from Table A2.2 that fishing only took place in Area 3 in that season. This would require interpolation for Area 4 given the $seas \times area$ interaction that is included in the model, with only information from 2009 informing that interpolation given that the 2002-2007 data are excluded from the analyses due to patchiness of data and low sample sizes.

The standardized CPUE for Area 8+ is adjusted for movement of lobster into the East of Hangklip Area. The proportion ($\frac{A_{8+,season}}{A_{8+}}$) is applied to adjust the Area 8+ area size (3927.31km^2) to include East of Hangklip (comprising a total area size of 161.96km^2). $A_{8+,season}$ is season-specific (the Area 8+ size is expanded in a linear fashion over the period 1987-1995) and A_{8+} is the area size of Area 8+. The resultant season-specific proportions applied to the exponent of the season factors are indicated in Table A2.9. The Area 8+ standardized CPUE index is then extended back to 1985 by scaling the pre-1992 standardized indices from the GLM applied in the past to standardize the Area 8 CPUE data ("Revised Area 8" in Figure 1 of Glazer and Butterworth, 2011 and reported in Table A2.10 below) so that they can be incorporated in the GLMM index. This was achieved by multiplying the pre-1992 GLM values (Table A2.10) by the ratio $\frac{\overline{Std\ CPUE_{GLMM,1992-1996}}}{\overline{Std\ CPUE_{\ GLM,1992-1996}}}$ in order to scale them to the GLMM index and then combine them with the GLMM index.

The resulting standardized trapboat CPUE indices at the time of this analysis are shown in Table A2.11 and Figures A2.1a-c respectively.

Extension for future seasons to provide OMP input

The OMP envisages future commercial trap CPUE data becoming available for super-areas 3+4, 7 and 8 respectively.

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

a) they will include co-variates as specified in Table A2.6, and calculate indices from the model outputs as indicated in Tables A2.7 and A2.8 (note that this means that values for past seasons shown in Table A2.9 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.

Reference

Glazer, J.P. and D.S. Butterworth. 2011. Updated GLM analyses for Area 8+. Unpublished Working Group Document: Fisheries/2011/MAR/SWG-WCRL 04. 10pp.

Table A2.1: Area 3+4 sample sizes by season and month. The shaded areas together indicate the data to be included in the GLM analyses. The portion in the lighter shaded area contribute to the final index of abundance. Records where n≤5 are excluded from the analyses.

Season	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	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
2007	9	21	4	5	6	18	9	26		98
2008	50	67	49	64	26	13	7			276
2009	52	131	48	9	23	9	3			275
2010	46	51	56	20	4	13	8			198
2011	40	72	35	51	18	10	15			241
2012	62	108	100	49	24	3	9			355
2013	56	127	35	19	22	10	9	1		279
2014	59	95	14	24	187	357				736
Total	11829	7677	5879	3039	2489	1469	630	132	73	33217

Table A2.2: Areas 3 and 4 sample sizes per season and month respectively given that there is a month/area interaction in the model.

	Area 3									Area 4									
Season	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Total**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Total**
1981	819	504	160	61					1544	499	8								507
1982	909	495	53	3					1460	407	1								408
1983	507	135							642	92	5	57	54						208
1984	401	245	159						805	185	6	69	97						357
1985	260	119	90	30					499	144									144
1986	424	245	63	26	56	29	118	24	985	120	95	82							297
1987	467	172	150	59	5				853	233	15	14	16	1					279
1988	319	176	298	250	123	33			1199	370	69		2	8					449
1989	227	248	301	238	235	114	173	43	1579	266	279	135	42	54	21	8			805
1990	639	446	744	415	346	236	80	4	2910	662	531	522	307	381	285	55	1		2744
1991	673	679	630	379	284	127	2		2774	879	314	271	6	114	49	66			1699
1992	260	42	147	10					459	300	311								611
1993	5								5	308	514	244							1066
1994	37	28	4	87	85	1			242	487	708	740	341	265	90	8			2639
1995	35		24						59	378	203	51	65			6			703
1996	55	25							80	87	150	93	87	20	3			71	511
1997			5						5		29	98	15	17	1				160
1998		28	6						34		13		15	56	5				89
1999		100	74	17	9				200		1	8	1						10
2000		47	139	128	63				377			2							2
2001		13	83	30	15	17	19	7	184			7			1				8
2002					1				1							11	15	2	28
2003		6	1	1	24		14	5	51				1						1
2004			13	15	9	9	10	6	62	1									1
2005														8	15				23
2006			1						1										
2007	9	21	4	5	2	14		22	77					4	4	9	4		21
2008	50	67	49	64	26	13	7		276										
2009	52	112	38	1	1				204		19	10	8	22	9	3			71
2010	46	22	41	20	4	13	8		154		29	15							44
2011	37	61	35	41	12	1	9		196	3	11		10	6	9	6			45
2012	58	42	89	3					192	4	66	11	46	24	3	9			163
2013	10	22	2		1				35	46	105	33	19	21	10	9	1		244
2014	1			1	17	162			181	58	95	14	23	170	195				555
Total	6300	4100	3403	1884	1318	769	440	111	18325	5529	3577	2476	1155	1171	700	190	21	73	14892

Table A2.3: Area 7 trapboat sample sizes per season and month. The shaded areas together indicate the data to be included in the GLM analyses. The portion in the lighter shaded area will contribute to developing a final index of abundance given the inclusion of a season/month interaction. Records where n ≤ 5 are also excluded from the analyses.

Season	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	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	488	597	621	330	83	175	127		1	1	2521
2007	47	245	323	361	132	247	108					1463
2008	78	201	329	289	249	192	89					1427
2009	78	324	268	159	87	24	15	35				990
2010	105	146	241	125	67	7	8	7				706
2011	25	135	224	224	194	87	69	32				990
2012	15	76	159	216	198	90	72	8				834
2013			102	84	84							270
2014		49	74	96	84							303
Total	4843	7257	8552	7307	4595	2835	2455	1623	137	86	159	39849

Table A2.4: Sample sizes per season and month for Areas 8, 10 and 11. Data from the shaded cells are included in the GLMM analyses of Area 8+

Season	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1992	4	47	113	212	208	249	297	181	62	61		1434
1993	4	94	22	122	176	213	299	140	290	145		1505
1994	4	51	279	249	190	313	237	138	72	38	13	1584
1995	5	22	49	171	288	184	236	186	148	54		1343
1996		5	138	223	225	215	198	244	432	109	7	1796
1997			43	61	215	190	413	337	253	149	54	1715
1998		18	28	36	164	175	171	333	413	247	248	1833
1999		8	22	121	174	386	360	242	172	146	90	1721
2000		1	9	24	143	165	393	285	207	110	125	1462
2001		2	10	29	175	234	181	236	342	571	621	2401
2002	4	24	33	53	78	159	232	242	359	364	608	2156
2003	7	12	48	154	318	309	349	311	383	391	306	2588
2004	19	25	20	84	214	310	344	466	426	500	670	3078
2005					90	311	203	793	390	270	342	2399
2006	17	42	56	75	476	380	708	294	421	769	818	4056
2007	1	18	164	162	244	381	183	646	330	511	453	3093
2008		18	147	90	257	323	352	349	531	259	301	2627
2009		26	155	232	521	332	286	315	288	333	354	2842
2010	1	22	147	87	311	113	330	270	421	288	268	2258
2011	12	42	82	93	144	208	403	296	442	326	360	2408
2012	6	64	70	43	135	306	391	318	547	254	292	2426
2013	1	13	104	117	217	448	353	518	453	321	501	3046
2014	5	77	92	285	218	256	385	244				1562
Total	90	631	1831	2723	5181	6160	7304	7384	7382	6216	6431	51333

Table A2.5: Sample sizes per season and sub-area for the Areas 8+ for the January to July period (as shown in the shaded area in Table A2.2). Data from cells where n ≤ 5 (as highlighted) are omitted from the analyses.

Season	SA1	SA2	SA3	SA4	SA5	SA6	SA10	SA11	Total
1992	248	590		233	41	73	76	61	1322
1993	363	413	18	302	68	18	15	65	1262
1994	523	546	13	211	66	22	54	43	1478
1995	628	357		80	28	11	109	49	1262
1996	601	447	38	296	33	45	133	82	1675
1997	534	613	22	98	41	71	131	2	1512
1998	243	736	43	133	14	22	114	15	1320
1999	347	580	46	267	5	47	152	33	1477
2000	560	215	62	188	24	45	121	11	1226
2001	602	366	17	91	1	9	105	16	1207
2002	491	269		222	18	41	77	38	1156
2003	757	480		265	141	95	86	48	1872
2004	663	336		256	61	397	76	75	1864
2005	124	418		414	95	536	124	76	1787
2006	172	313		699	34	954	164	74	2410
2007	260	436		564	133	391	196	130	2110
2008	141	342	1	675	189	361	222	118	2049
2009	217	628	1	491	161	242	297	92	2129
2010	345	408		395	108	335		88	1679
2011	45	451		537	263	274		98	1668
2012	159	360		507	178	511		95	1810
2013	210	561	1	392	426	486		134	2210
2014	110	572	12	154	92	427		113	1480
Total	8343	10437	274	7470	2220	5413	2252	1556	37965

Table A2.6: Models applied to each super-area.

Area	Model Type	Model
3+4	GLM	$\ell n(CPUE_{seas}) = \alpha + \beta_{seas} + \gamma_{month} + \kappa_{area} + (seas \times month) + (seas \times area) + \varepsilon$
7	GLM	$\ell n(CPUE_{seas}) = \alpha + \beta_{seas} + \gamma_{month} + (seas \times month) + \varepsilon$
8	GLMM	$\ell n(CPUE_{seas}) = \alpha + \beta_{seas} + \gamma_{month} + \eta_{subarea} + (seas \times month) + (seas \times subarea) + \varepsilon$

Table A2.7: Equations applied to obtain final indices of abundance for each super-area.

Area	Equation
3+4	$\widehat{CPUE}_{seas} = (\sum_{month=Dec}^{Feb} (\sum_{area=3}^{4} e^{(\alpha+\beta_{seas}+\gamma_{month}+\kappa_{area}+(seas\times month)+(seas\times area))}) \times A_{area})/ \sum_{month=Dec}^{Feb} 1$
7	$\widehat{CPUE}_{seas} = (\sum_{month=Dec}^{Mar} e^{(\alpha+\beta_{seas}+\gamma_{month}+seas\times month)})/ \sum_{month=Dec}^{Mar} 1$
8	$\widehat{CPUE}_{seas} = e^{seas} \times (\frac{A_{8+,seas}}{A_{8+}})$

Table A2.8: Sizes (km^2) of Areas 3 and 4.

Area 3	Area 4
1141	2378

Table A2.9: Season-specific proportions applied to the standardized CPUE of Area 8+.

Season	proportion
≤1986	1
1978	1.005
1988	1.009
1989	1.014
1990	1.018
1991	1.023
1992	1.027
1993	1.032
1994	1.037
≥1995	1.041

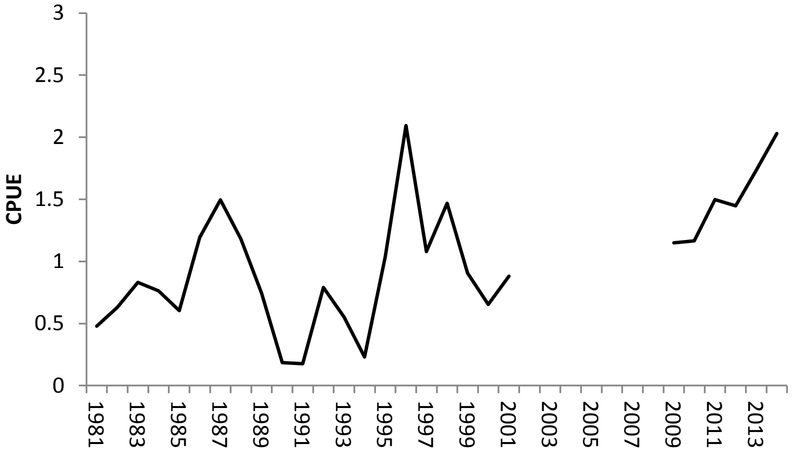
Table A2.10: The standardized CPUE index of abundance derived from the GLM applied in the past to the Area 8 CPUE data ("Revised Area 8" as depicted in Figure 1 of Glazer and Butterworth, 2011a). The pre-1992 indices shown here are scaled to the GLMM index so that they can be incorporated in the GLMM index.

Season	CPUE
1985	0.744
1986	1.025
1987	0.858
1988	0.960
1989	0.813
1990	0.372
1991	0.631
1992	0.920
1993	0.933
1994	0.857
1995	1.014
1996	0.976
1997	0.989
1998	0.985
1999	1.063
2000	1.208
2001	1.419
2002	1.649
2003	1.156
2004	1.131
2005	1.002
2006	1.227
2007	0.910
2008	1.060
2009	1.098

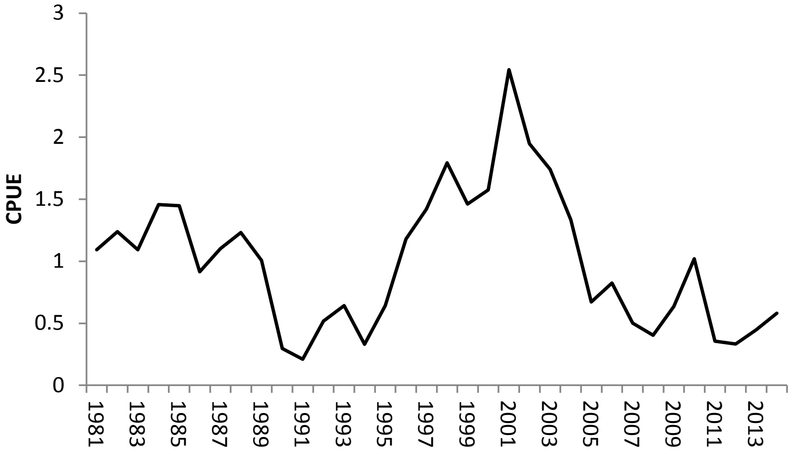
Table A2.11: Trapboat standardized CPUE per super-area for analyses using data up to 2013 and for part of 2014. Each index has been normalized to its mean.

Season	Area 3+4	Area 7	Area 8+
1981	0.4782	1.0925	
1982	0.6303	1.2387	
1983	0.8302	1.0939	
1984	0.7623	1.4577	
1985	0.6043	1.4469	0.7927
1986	1.1940	0.9162	1.0926
1987	1.4944	1.1009	0.9145
1988	1.1815	1.2310	1.0225
1989	0.7443	1.0061	0.8667
1990	0.1853	0.2976	0.3967
1991	0.1771	0.2110	0.6719
1992	0.7901	0.5166	0.8469
1993	0.5506	0.6434	1.0420
1994	0.2313	0.3308	0.9147
1995	1.0391	0.6433	1.2415
1996	2.0947	1.1787	0.9621
1997	1.0783	1.4207	1.2422
1998	1.4671	1.7927	1.1443
1999	0.9073	1.4612	1.2507
2000	0.6541	1.5756	1.3088
2001	0.8823	2.5451	1.5450
2002		1.9487	1.8006
2003		1.7405	1.3687
2004		1.3347	1.2995
2005		0.6727	0.9815
2006		0.8255	0.8568
2007		0.5007	0.7702
2008		0.4040	0.8660
2009	1.1494	0.6355	0.8709
2010	1.1646	1.0202	1.0062
2011	1.4983	0.3553	1.0281
2012	1.4468	0.3320	0.8057
2013	1.7329	0.4477	0.5956
2014	2.0311	0.5818	0.4944

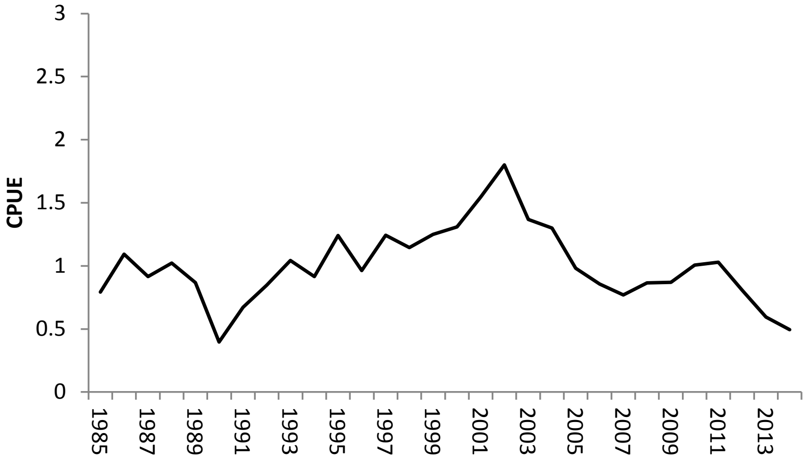
a) Area 3+4



b) Area 7



c) Area 8+



Figures A2.1a-c: Trapboat standardized CPUE indices per super-area. Each index has been normalized to its mean.

Annexure 2A

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

B. Super-area specific exclusions

Area 3+4

1. All records not pertaining to Areas 3 and 4
2. 2002≤season≤2008 (patchy data)
3. June-July (patchy data)
4. February 1982 (n≤5)
5. April 1996 (n≤5)
6. April 1997 (n≤5)
7. April 1998 (n≤5)
8. May 2009 (n≤5)
9. March 2010 (n≤5)
10. April 2012 (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)
10. April 2013 (n≤5)

Area 8

1. All records not pertaining to Areas 8, 10 and 11
2. Sub-area > 6 of Area 8 (valid sub-areas in Area 8 are 1-6)
3. Sub-area 3 of Area 8 (patchy data)
4. August-December
5. Area 11 in 1997 (n≤5)
6. Sub-area 5 of Area 8 in 1999 (n≤5)
7. Sub-area 5 of Area 8 in 2001 (n≤5)

Appendix 3: Hoopnet CPUE analyses for inputs to the OMP

Introduction

Generalized Linear Mixed Models (GLMM) have been applied to standardize the commercial hoopnet CPUE data from Area 1+2 and Area 8 respectively, 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. Area 7 is excluded from the hoopnet analyses given that hardly any hoopnet fishing has taken place in that particular area.

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 hoopnet dataset for Area 1+2 covers the period 1971 – 2014, the 2014 data being partial since at the time the analyses were conducted the fishing season was still underway. Although data exist since 1971, the analyses only take into account data from 1993 since it is only from that season onwards that detailed, reliable information is available.

The dataset for Areas 3+4, 5+6 and 8 covers the period 1981-2014, the 2014 data being partial since at the time the analyses were conducted the fishing season was still underway. More refined data, detailing catches at a sub-area level, are only available since 1992 for these areas.

Table A3.1 indicates the sample sizes per season and month for Area 1+2, while Tables A3.2-3.5 indicate the sample sizes per season and month for Areas 3+4, 5+6 and 8 respectively, where the shaded areas indicate the data which were considered in the GLM/GLMM 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 3A.

Both deckboat and bakkie data are included in the analyses of Areas 1+2 and 3+4 since a fair amount of deckboat fishing took place in those two areas in the earlier seasons. Only bakkie data are included in the analyses of the other super-areas.

The models

The models applied to the data from each area are shown in Table A3.6. Diagnostic tests related to the studentized residuals obtained from the models of Areas 3+4, 5+6 and 8 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 ±1 standard deviations for Area 3+4 and ±2 standard deviations for Areas 5+6 and 8 respectively.

The equations applied to obtain the area-specific standardized CPUE indices are shown in Table A3.7. Given that the model for 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. The sizes of Areas 5 and 6 are shown in Table A3.8.

Interpolation was used to fill empty interaction cells where applicable. This involved taking the average of the $\ell n\widehat{CPUE}_{seas,m}$ 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	**January**	**February**	**March**
1993		X	
1994	X	Empty Cell	X
1995		X	

Although data exist for the period 1997-2001 for Area 5+6, fishing only took place in Area 5 in those seasons. As a result there are empty cells for the season/area 6 interactions for those seasons. The standardized indices for those seasons are therefore not included in the final index used in the OMP.

The standardized CPUE index for Area 1+2 is extended back to 1976 by scaling the pre-1993 nominal CPUE (Table A3.9) to the GLMM index by multiplying each value by the ratio $\frac{\overline{CPUE}_{glmm,1993-2005}}{\overline{CPUE}_{bakkie\ nominal,1993-2005}}$.

The standardized CPUE index for Area 8 is adjusted for movement of lobster into the East of Hangklip area i.e. $\widehat{CPUE}_{seas} = e^{seas} \times (\frac{A_{8,seas}}{A_8})$. The proportion $(\frac{A_{8,seas}}{A_8})$ is applied to adjust the Area 8 area size (2621 km^2) to include East of Hangklip (comprising a total area size of 161.96km^2). $A_{8,seas}$ is season-specific (the Area 8 size is expanded in a linear fashion over the period 1987-1995) and A_8 is the area size of Area 8. The resultant season-specific proportions applied to the exponent of the season factors are indicated in Table A3.10. The Area 8 standardized CPUE index is then extended back to 1985 by scaling the pre-1992 standardized indices from the GLM applied in the past to standardize the Area 8 CPUE data ("Revised Area 8" in Figure 4 of Glazer and Butterworth, 2011 and reported in Table A3.11 below) so that they can be incorporated in the GLMM index. This was achieved by multiplying the pre-1992 GLM values (Table A3.11) by the ratio

$\frac{\overline{Std\ CPUE_{GLMM,1992-1996}}}{\overline{Std\ CPUE_{GLM,1992-1996}}}$ in order to scale them to the GLMM index and then combine them with the GLMM index.

The resulting standardized hoopnet CPUE indices are shown in Table A3.12-3.13 and Figures A3.1 – A3.4.

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:

d) they will include co-variates as specified in Table A3.6, and calculate indices from the model outputs as indicated in Tables A3.7 - A3.11 (note that this means that values for past seasons shown in Tables A3.9 and A3.11 will be updated slightly each season);
e) 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;
f) the procedure described above to interpolate any missing values for the season-month interaction cells will be as described above;
g) the procedure for excluding outliers (related to the studentized residuals) will be as specific above; and
h) there must be more than five data points for estimation of a season-month interaction term to be attempted within the GLM.

References

Glazer, J.P. and D.S. Butterworth. 2011. Updated GLM analyses for Area 8+. Unpublished Working Group Document: Fisheries/2011/MAR/SWG-WCRL 04. 10pp.

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 A3.1: Area 1+2 hoopnet (bakkie+deckboat) sample sizes per season and month to 2013 and for part of 2014 (after the exclusion of outliers as reported in Annexure 3A).

Season	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	326	184	185	106	97	35		935
2007		41	103	147	159	186	83		719
2008	37	233	117	141	104	76	50		758
2009	83	144	125	83	29	68	2		534
2010	103	271	70	35	52				531
2011	212	51	88	91	45	6	8		501
2012	59	75							134
2013	58	44	89	33	19	16	19		278
2014	69	189	4	97	76	48			483
Total	998	3163	2335	4075	3204	2166	1044	43	17028

Table A3.2: Area 3+4 bakkie+deckboat sample sizes per season and month. The shaded areas together indicate the data to be included in the GLM analyses. The portion in the lighter shaded area contributes to the final index of abundance. Records where n ≤ 5 are also excluded from the analyses.

Season	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	154	214	302	154	72	26			978
2007	20	184	324	632	125	23		4			1312
2008	95	226	87	249	202	59	5				923
2009	13	211	391	241	65	61	2	5			989
2010	71	103	51	178	286	186	85	62			1022
2011	25	176	368	142	142	21	20	3			897
2012	14	52	178	420	230	109	72	4			1079
2013	16	176	430	411	104	54	12	4			1207
2014	28	236	196	16	69	126					671
Total	7730	10007	10129	7439	5629	3177	1268	599	116	1	46095

Table A3.3: Area 5+6 bakkie sample sizes per season and month. The shaded areas together indicate the data to be included in the GLM analyses. The portion in the lighter shaded area contributes to the final index of abundance. Records where n ≤ 5 are also excluded from the analyses.

Season	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	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	36	82	40	131	33	1	463
2007	6	32	87	144	140	87		7		503
2008	15	22	48	92	125	58	6	2		368
2009	8	90	55	83	68	25	17	9		355
2010	17	62	61	54	49	41	48	8		340
2011	11	23	112	85	33	39	49	30		382
2012	5	30	78	120	83	42	10	9		377
2013	4	48	69	37	43	30	26	15		272
2014	23	68	47	38	27	22	14	3		242
Total	2417	3006	3487	2262	1737	1379	960	632	1	15881

Table A3.4: Sample sizes per season and month for Areas 8. Data from the shaded cells are included in the GLMM analyses.

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
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	258	405				929
2002	1	7	63	76	162	329	403	558	42		1	1642
2003	5	17	92	56	123	323	448	644				1708
2004	1	1	42	86	219	292	310	539	1		2	1493
2005				10	133	119	220	224				706
2006	8	44	45	96	188	138	332	291	1			1143
2007		13	133	161	161	227	32	143				870
2008	19	23	112	181	114	85	66	130				730
2009	2	36	47	132	198	85	110	66				676
2010	6	12	45	92	180	94	132	123				684
2011	5	30	35	129	95	118	151	194				757
2012	5	30	55	112	146	238	179	171				936
2013	13	62	127	93	102	242	140	230	1			1010
2014	25	88	99	165	188	190	81	61				897
Total	404	1014	1679	2201	3053	3314	3543	4225	287	158	79	19957

Table A3.5: Sample sizes per season and sub-area for the January to June period (as shown in the shaded area of Table A3.6). Data from the shaded cells are included in the GLMM analyses.

seaso	SA1	SA2	SA3	SA4	SA5	SA6	Total
1992	147	328	112				587
1993	115	422	230				767
1994	384	127	118	59			688
1995	207	186		41			434
1996	173	137	60				370
1997	148	166	44	4		2	364
1998	55	131	140				326
1999	29	6	369				404
2000	54	19	300	20		2	395
2001	625	6	283	8	1	6	929
2002	942	518	41	65		25	1591
2003	698	614	20	289	2	63	1686
2004	411	743	7	261	3	63	1488
2005	206	390	17	69	1	23	706
2006	262	523	47	206		52	1090
2007	223	228	51	304		51	857
2008	149	98	29	356		56	688
2009	102	166	63	271		36	638
2010	189	152	47	244		34	666
2011	71	232	32	363		24	722
2012	109	249	118	381		44	901
2013	236	308	83	248	4	55	934
2014	232	252	102	162	1	35	784
Total	5508	5664	2197	3142	11	496	17018

Table A3.6: Models applied to each super-area.

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

Table A3.7: 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 A3.9 and A3.10.

Area	Equation
1+2	$\widehat{CPUE}_{seas} = e^{seas}$
3+4	$\widehat{CPUE}_{seas} = \sum_{month=Dec}^{Feb} e^{(\alpha+\beta_{seas}+\gamma_{month}+\tau_{bakkies}+seas\times month)} / \sum_{month=Dec}^{Feb} 1$
5+6	$\widehat{CPUE}_{seas} = \sum_{month=Dec}^{Jan} \left(\sum_{area=5}^{6} \left(e^{(\alpha+\beta_{seas}+\gamma_{month}+\kappa_{area}+(seas\times month)+(seas\times area)+(month\times area))}\right) \times A_{area}\right) / \sum_{month=Dec}^{Jan} 1$
8	$CPUE_{seas} = e^{seas} \times \left(\frac{A_{8,seas}}{A_8}\right)$

Table A3.8: Area sizes (km^2) of Areas 5 and 6.

Area 5	Area 6
561	834

Table A3.9: 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 A3.10: Season-specific proportions applied to the standardized CPUE of Area 8+.

Season	proportion
≤1986	1
1978	1.007
1988	1.014
1989	1.021
1990	1.027
1991	1.034
1992	1.041
1993	1.048
1994	1.055
≥1995	1.062

Table A3.11: The standardized CPUE index of abundance derived from the GLM applied in the past to the Area 8 CPUE data ("Revised Area 8" as depicted in Figure 4 of Glazer and Butterworth, 2011). The pre-1992 indices shown here are scaled to the GLMM index so that they can be incorporated in the GLMM index.

Season	CPUE
1986	0.312
1987	0.474
1988	0.486
1989	
1990	0.648
1991	0.365
1992	0.720
1993	0.818
1994	1.202
1995	1.227
1996	1.074
1997	1.302
1998	1.608
1999	1.467
2000	1.438
2001	1.410
2002	1.046
2003	0.969
2004	1.053
2005	0.929
2006	0.950
2007	1.101
2008	1.168
2009	1.231

Table A3.12: 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	CPUE
1976	1.077
1977	0.709
1978	0.942
1979	0.932
1980	1.062
1981	1.251
1982	
1983	
1984	
1985	1.518
1986	1.177
1987	2.036
1988	1.045
1989	0.879
1990	0.701
1991	0.691
1992	0.953
1993	0.720
1994	0.556
1995	0.795
1996	1.111
1997	0.953
1998	0.834
1999	0.611
2000	0.912
2001	1.140
2002	1.134
2003	0.877
2004	0.855
2005	1.404
2006	1.308
2007	1.419
2008	1.148
2009	1.578
2010	1.042
2011	0.851
2012	0.819
2013	0.934
2014	0.998

Table A3.13: Standardized CPUE indices for Areas 3+4, 5+6 and 8 respectively. Each index has been normalized to its mean.

Season	Area 3+4	Area 5+6	Area 8
1981	0.7526		
1982	0.6041		
1983	1.4111		
1984	1.1188		
1985	0.6387		
1986	1.0200	1.6495	0.3536
1987	1.4176		0.5367
1988	1.0726	1.6827	0.5504
1989	0.8035	1.1294	
1990	0.2231	1.0285	0.7345
1991	0.2478	0.5492	0.4135
1992	0.9458	0.6962	0.7266
1993	1.4131	0.5211	0.9079
1994	0.4430	0.1944	1.3180
1995	1.0849	0.3829	1.5056
1996	1.4200	0.7920	1.2512
1997	0.9319		1.4841
1998	0.9100		1.6581
1999	0.7797		1.1934
2000	0.4607		1.4000
2001	2.7337		1.1797
2002	0.6793	1.0098	1.2205
2003	1.2484	0.6475	1.1222
2004	0.5292	0.5737	1.0720
2005	0.4864	0.7896	1.1031
2006	0.3881	0.8675	0.9895
2007	0.7847	1.0694	0.8636
2008	1.2857	1.3570	0.9127
2009	1.3653	1.1158	1.0538
2010	1.2629	1.3820	1.1493
2011	1.6296	1.4950	1.0495
2012	0.8564	1.4128	0.9401
2013	0.9738	1.3251	0.7782
2014	2.0773	1.3287	0.5324

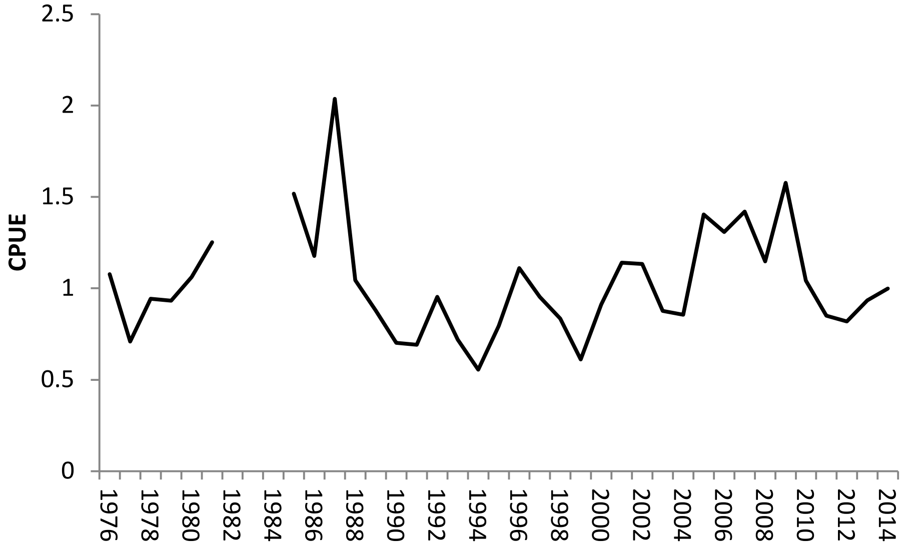
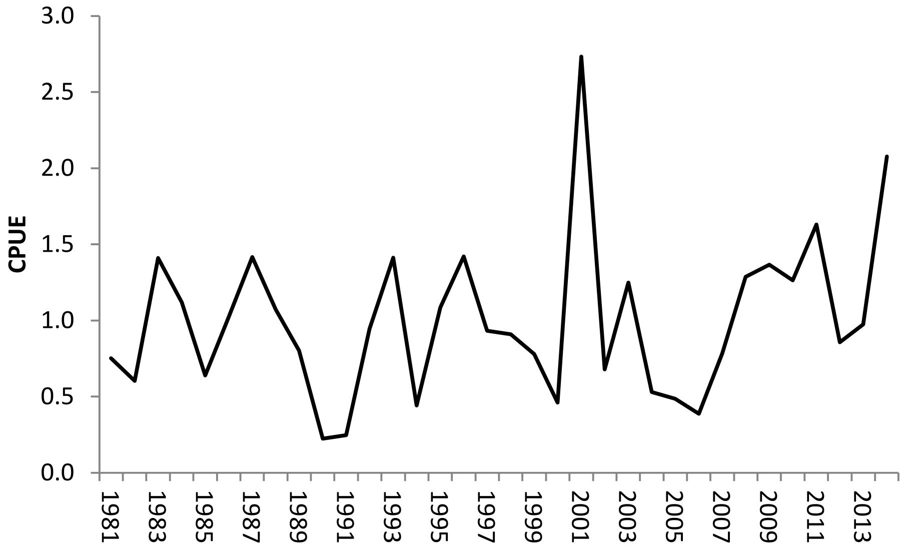
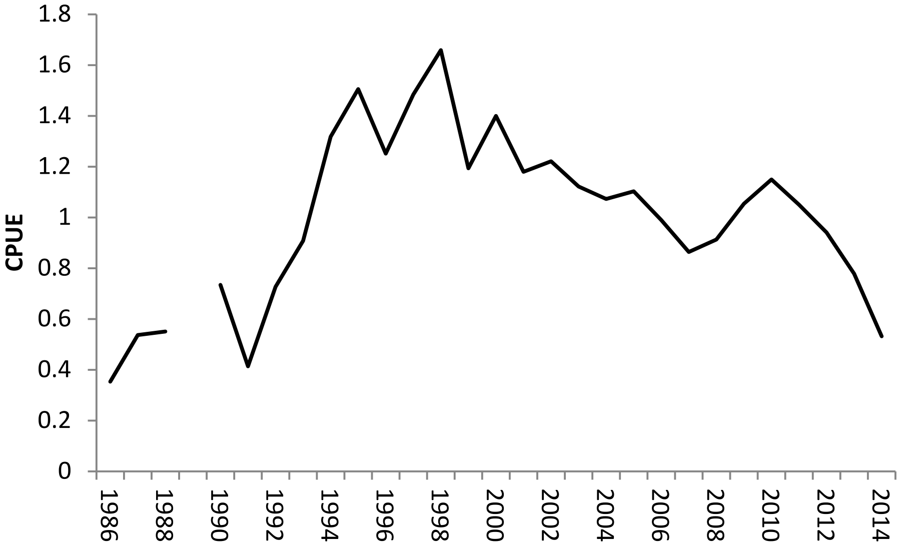


Figure A3.1: Standardized CPUE index for Area 1-2. The GLMM index has been normalized to its mean, and the pre-1993 nominal bakkie CPUE data have been scaled to the GLMM index.



Figures A3.2: Standardized CPUE index for Area 3-4. The index has been normalized to its mean.

Figures A3.3: Standardized CPUE index for Area 5-6. The index has been normalized to its mean.



Figures A3.4: Standardized CPUE index for Area 8. The index has been normalized to its mean.

Annexure 3A

Data exclusions applied to 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. General exclusions

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. Super-area specific exclusions

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 ($n \leq 5$)
7. May 2008 ($n \leq 5$)
8. May 2009 ($n \leq 5$)

Area 5+6

1. All records not pertaining to Area 5 or 6
2. June (patchy data /small sample sizes in recent seasons)
3. July (patchy data)
4. Area = 6 and season = 1999 (small sample size – problematic in season/area interaction)
5. Season 1987 (patchy data)
6. Season 2001 (patchy data)
7. February 1988 ($n \leq 5$)
8. May 1989 ($n \leq 5$)
9. May 1990 ($n \leq 5$)
10. April 1997 ($n \leq 5$)
11. November 2012 ($n \leq 5$)
12. November 2013 ($n \leq 5$)

Area 8

1. All records not pertaining to Area 8
2. Sub-area > 3 (invalid sub-areas)

Appendix 4: FIMS analyses to provide inputs to the OMP

Introduction

The methodology used is as was updated in 2009. 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 was also changed slightly. These calculations are extended below to cover also the 2009/10 -2014/15 seasons.

Data

The FIMS data analysed covers the period 1992/93 to 2014/15. A data validation exercise in 2009 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:

$$CPUE^{\ell}_{y,z} = \frac{\sum_{i=1}^{z_s} a_i^z C_{y,i}^{\ell,z}}{\sum_{i=1}^{z_s} a_i^z}, \qquad \text{(A4.1)}$$

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:

$$SE\left(CPUE^{\ell}_{y,z}\right) = \sqrt{\frac{\sigma^2_{y,z,\ell} \sum_{i=1}^{z_s} \left(a_i^z\right)^2}{\left(\sum_{i=1}^{z_s} a_i^z\right)^2}}, \qquad \text{(A4.2)}$$

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:

$$CPUE_y = \sum_{z=1}^{s} p_z^A CPUE_{y,z} \,, \tag{A4.3}$$

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:

$$SE(CPUE_y) = \sqrt{\sum_{z=1}^{s} (p_z^A)^2 SE(CPUE_{y,z})^2} \,, \tag{A4.4}$$

where $SE(CPUE_{y,z})$ 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.

Results

Table A4.1 reports the FIMS CPUE indices for each individual Zone for rock lobsters measuring more than 60 cm together with their sampling standard errors. These results were plotted in Figure A4.1.

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.

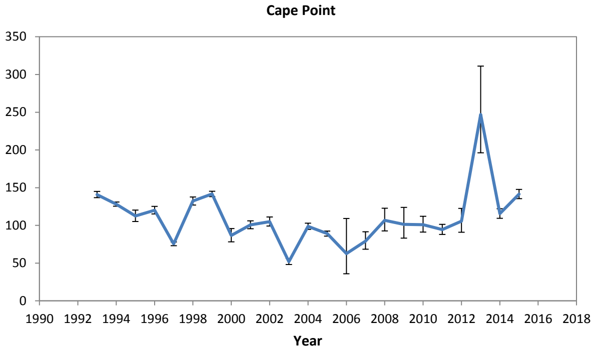
Table A4.1. FIMS CPUE series for each individual Zone and their corresponding standard errors.

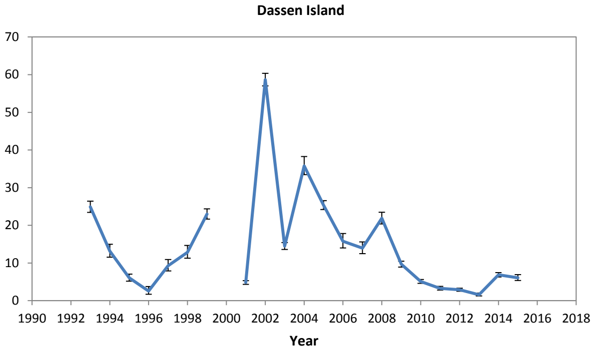
Year	Zone			
	Cape Point	**Dassen Island**	**Saldanha Bay**	**Lambert's Bay**
1992/93	140.75 (17.30)	24.89 (4.37)	2.72 (0.87)	3.04 (1.22)
1993/94	128.18 (13.47)	13.16 (3.44)	0.61 (0.67)	0.17 (0.06)
1994/95	112.43 (20.97)	6.06 (1.73)	0.82 (0.44)	0.19 (0.07)
1995/96	120.07 (17.61)	2.54 (1.20)	0.18 (0.06)	4.23 (1.04)
1996/97	75.50 (9.572)	9.30 (2.73)	0.65 (0.47)	9.16 (2.14)
1997/98	132.26 (19.17)[†]	12.84 (3.38)	0.11 (0.05)	0.09 (0.05)
1998/99	141.64 (16.32)	22.97 (4.02)	3.40 (1.00)	1.65 (0.55)
1999/00	86.60 (20.02)*			
2000/01	100.71 (16.60)	4.81 (1.12)	0.18 (0.10)	1.21 (0.18)
2001/02	105.01 (18.17)	58.66 (7.13)	0.08 (0.06)	0.18 (0.09)
2002/03	52.02 (10.43)	14.49 (2.62)	0.19 (0.17)	0.39 (0.22)
2003/04	98.67 (14.48)	35.78 (6.70)	0.28 (0.39)	0.34 (0.20)
2004/05	89.05 (12.35)	25.36 (3.94)	0.07 (0.03)	0.35 (0.24)
2005/06	62.71 (35.89)[†]	15.79 (3.97)	0.24 (0.06)	1.71 (0.72)
2006/07	79.18 (21.90)	13.96 (3.39)	0.12 (0.14)	0.24 (0.09)
2007/08	106.65 (29.10)	21.88 (4.21)	1.27 (1.34)	0.27 (0.19)
2008/09	101.43 (33.20)	9.67(1.97)	0.76 (0.31)	1.55 (0.51)
2009/10	101.02 (23.59)	5.09 (1.18)	0.71 (0.59)	0.01 (0.01)
2010/11	94.41 (18.17)	3.27 (0.92)	0.59 (0.37)	3.86 (1.39)
2011/12	105.61 (29.65)	2.89 (0.78)	2.32 (1.67)	1.23 (0.38)
2012/13	247.06 (87.33)	1.59 (0.58)	2.11 (2.48)	0.41 (0.15)
2013/14	115.58 (19.34)	6.86 (1.43)	0.38 (0.16)	6.18 (4.24)
2014/15	141.51 (41.36)	6.09 (1.59)	0.60 (0.27)	0.37 (0.11)

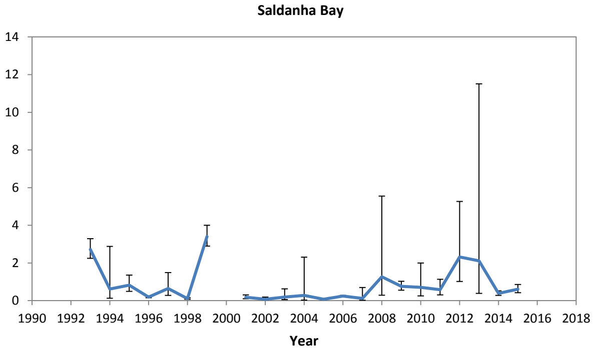
* Based on only one leg of the survey.

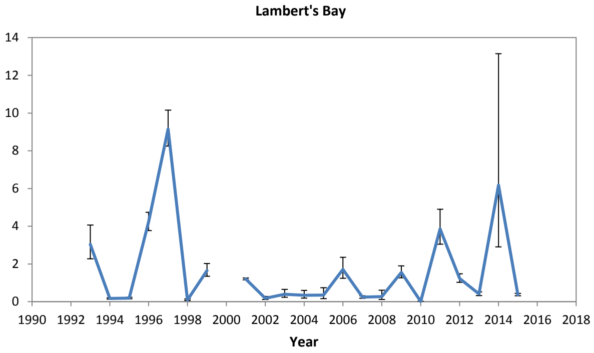
† Standard error based on an estimate (see text) because only one station was sampled in a leg for a particular Hotspot.

Figure A4.1. FIMS CPUE series (with 95% confidence intervals) for each Zone. In this plot the period shown as 1993 corresponds to the 1992/93 season, and so on.









Appendix 5: Catch data used in the OMP

Table A5.1: Total (all super-areas combined) Offshore commercial, Recreational, Near-shore commercial and Interim relief/subsistence catch estimates (all in MT).

Season	Offshore Commercial	Recreational	Near-shore Commercial	Interim relief/Subsistence
2005	1998	320		
2006	3091	300		63
2007	1863	261	451	174
2008	2062	243	451	170
2009	2022	216	451	278
2010	1979	107	451	270
2011	1540	183	451	251
2012	1540	183	451	251
2013	1557	84	451	276
2014	1120	69	376	235

Data sources

Commercial catches: van Zyl, D. (2015). West coast rock lobster annual TAC, Catch, Effort and CPUE per Area. DAFF document, FISHERIES/2015/JUL/SWG/WCRL/17.

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). A final agreed set of recreational catch estimates is reported in Johnston and Butterworth (2010). The 2011-2014 recreational estimates are assumed to be equivalent to the recreational allowances made by the OMP.

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

Interim Relief/subsistence catch estimates:

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

Van Zyl, D. and S.J. Johnston. 2010. Interim relief phase IV (2009/2010) season. Fisheries/2010/Aug/SWG-WCRL/18.

Van Zyl, D. and S.J. Johnston. 2011. Interim relief phase I (2006/2007) season. Fisheries/2010/Oct/SWG-WCRL/05.

Johnston, S.J. 2011. Task group report on west coast rock lobster interim relief. Fisheries/2010/Oct/SWG-WCRL/07.

Johnston, S.J. 2011. Estimate of Interim Relief take for the 2010/2011 season. Fisheries/2011/Mar/SWG-WCRL/09.

Reference

Johnston, S.J. and D.S. Butterworth. 2010. Rock lobster Scientific working group agreed recreational catch estimates. FISHERIES/2010/AUG/SWG-WCRL/19.

Appendix 6: PROCEDURES FOR DEVIATING FROM OMP OUTPUT FOR THE RECOMMENDATION FOR A TAC, AND FOR INITIATING AN OMP REVIEW FOR WEST COAST ROCK LOBSTER

Preamble

Currently scientific recommendations for management controls (e.g. total allowable catch (TAC) or total allowable effort (TAE)) for South Africa’s major fisheries are provided by Operational Management Procedures (OMPs). These are pre-agreed formulae for computing these control levels (usually annually), based on pre-agreed resource monitoring data inputs. This combination of formulae and data will have been simulation tested to ensure anticipated performance that is adequately robust given inevitable scientific uncertainties about data and models of the resource dynamics and fishery. (Typically these tests are divided into a core set (or “Reference Set”) of “Operating Models” for the underlying dynamics, which cover the more plausible scenarios that have quantitatively important implications, and “Robustness tests” which involve operating models for scenarios considered relatively less plausible or important.)

The intention is that these OMPs be used on a routine basis to provide such scientific management advice, subject to regular four-yearly reviews. However, occasionally “Exceptional Circumstances” can arise which may indicate the need for recommendations to deviate from the outputs from such OMPs, or necessitate bringing the regular review forward. The purpose of this document is to specify the procedures governing the identification of such circumstances, and the resultant actions that may follow.

This document is constructed as a template that applies generally to OMPs, whatever the fishery to which they apply, but it does also include sections which are fishery-specific. Places where entries pertinent to a specific OMP are to be made are indicated by [ ]. These entries, and possible additions to them, require review and finalisation by the relevant DAFF[5] Scientific Working Group in parallel with adoption of a new/revised OMP for a specific fishery.

Note that purely for simplicity of expression, the text that follows is written as if a global TAC were the only management recommendation output by an OMP. However, the provisions following should be understood to apply equally should global effort, either on its own or in conjunction with a global TAC be the output, and similarly if either or both of such measures are disaggregated by space or time or both.

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[5] Note “DAFF” in this Appendix refers to DAFF Fisheries Branch.

When an OMP is adopted, the Working Group concerned will ratify a document that contains a complete specification of the formulae used by the OMP to compute recommended management control levels, and of the data to be input. The latter may, as appropriate, contain details concerning pre-processing of such data: for example the specification of a Generalised Linear Model (GLM) to standardise a resource abundance index for the effects of co-variates other than the year factor related to the abundance trend.

On a number of occasions below, the text requires judgements to be made of whether an effect is “appreciable” (for example, whether an abundance survey result is *appreciably* outside the range predicted in the simulation tests used in selecting the OMP). Such judgements are the province of the Scientific Working Group concerned.

Simulation tests of OMPs assume, at basis, that future resource monitoring data required for input into the OMP will indeed become available as assumed, and that OMP recommendations will be implemented (and in an effective manner). Specific OMPs may include (simulation tested) rules for dealing with the absence of (some) such data, and to indicate adjustments perhaps necessary if implementation differs from the scientific recommendation arising from a previous application of the OMP. To the extent that circumstances arise that are not covered by such rules, and are adjudged by the Working Group to have a likely appreciable impact on the performance of the OMP that would otherwise have been anticipated, the Working Group may consider such an instance of “Exceptional Circumstances” as conceived in the text following.

1. Metarule Process

Metarules can be thought of as “rules” which prespecify what should happen in unlikely, Exceptional Circumstances when application of the TAC generated by the OMP is considered to be highly risky or highly inappropriate. Metarules are not a mechanism for making small adjustments, or ‘tinkering’ with the TAC from the OMP. It is difficult to provide firm definitions of, and to be sure of including all possible, Exceptional Circumstances. Instead, a process for determining whether Exceptional Circumstances exist is described below (see Fig. 1). The need for invoking a metarule should be evaluated by the DAFF [West Coast Rock Lobster] Working Group (hereafter indicated by WG), but only provided that appropriate supporting information is presented so that it can be reviewed at a WG meeting.

1.1 Description of Process to Determine Whether Exceptional Circumstances Exist

While the broad circumstances that may invoke the metarule process can be identified, it is not always possible to pre-specify the data that may trigger a metarule. If a WG Member or Observer, or DAFF Management, is to propose an Exceptional Circumstances review, then such person(s) must outline in writing the reasons why they consider that Exceptional Circumstances exist, and must either indicate where the data or analyses are to be found supporting the review, or must supply those data or analyses in advance of the WG meeting at which their proposal is to be considered.

Every year the WG will:

- Review population and fishery indicators, and any other relevant data or information on the population, fishery and ecosystem, and conduct a simple routine updated assessment (likely no more than core reference set models used in the OMP testing refitted taking a further year's data into account).
- On the basis of this, determine whether there is evidence for Exceptional Circumstances.

Examples of what might constitute an Exceptional Circumstance in the case of [West Coast Rock lobster] include, but are not necessarily limited to:

- CPUE trends that are appreciably outside the bounds predicted in the OMP testing.
- FIMS trends that are appreciably outside the bounds predicted in the OMP testing.
- Somatic growth trends that are appreciably outside the bounds predicted in the OMP testing.
- Allocations or catches that are appreciably larger than the OMP recommended.

Every two years the WG will:

- Conduct an in depth stock assessment (more intensive than the annual process above, and in particular including the conduct of a range of sensitivity tests).
- On the basis of the assessment, indicators and any other relevant information, determine whether there is evidence for Exceptional Circumstances.

The primary focus for concluding that Exceptional Circumstances exist is if the population assessment/indicator review process provides results appreciably outside the range of simulated population and/other other indicator trajectories considered in OMP evaluations. This includes the core (Reference case or set of) operating models used for these evaluations, and likely also (though subject to discussion) the operating models for the robustness tests for which the OMP was considered to have shown adequate performance. Similarly, if the review process noted regulatory changes likely to effect appreciable modifications to outcomes predicted in terms of the assumptions used for projections in the OMP evaluations (e.g. as a result, perhaps, of size limit changes or closure of areas), or changes to the nature of the data collected for input to the OMP beyond those for which allowance may have been made in those evaluations, this would constitute grounds for concluding that Exceptional Circumstances exist in the context of continued application of the current OMP.

(Every year) IF the WG concludes that there is no or insufficient evidence for Exceptional Circumstances, the WG will:

- Report to the Chief Director Research, DAFF, that Exceptional Circumstances do not exist.

IF the WG has agreed that Exceptional Circumstances exist, the WG will:

- Determine the severity of the Exceptional Circumstances.
- Follow the “Process for Action” described below.

1.2 Specific issues that will be considered annually (regarding Underlying Assumptions of the Operating Models (OMs) for the OMP Testing Process)

The following critical aspects of assumptions underlying the OMs for [West Coast Rock lobster] need to be monitored after OMP implementation. Any appreciable deviation from these underlying assumptions may constitute an Exceptional Circumstance (i.e. potential metarule invocation) and will require a review, and possible revision, of the OMP:

- The areal distributions of poaching and recreational catches (the latter as monitored using telephone surveys) do not differ substantially from assumptions made for OM projections.
- Selectivities-by-size do not differ substantially from assumptions made for OM projections.
- New CPUE, FIMS and somatic growth estimates are within the bounds projected by the OMs.
- An allocation to or catch made by a sector is appreciably greater than the OMP recommendation, either globally or within a super-area. (For the recreational sector, this will be determined from telephone survey and permit sale information.)
- The nomalised gear-aggregated abundance index for a super-area (J_{area}) falls below the threshold for that super-area (see Low Abundance rule in main text).
- A walk-out of appreciable size appears imminent because of environmental conditions (this usually occurs near the end of the season), in which case:

    a) Transfers from other areas, within the allocation to each sector concerned, may be permitted to be taken from lobsters in the vicinity where the walkout is anticipated.
    b) The rights holders in the area will be asked to catch their remaining allocations as soon as possible.

c) If an allocation is unable to be caught prior to the walkout, then the remaining allocation may be allowed to be caught in adjacent areas.
d) The fishery may be closed to all sectors in that effected area/areas once the walkout occurs, for the remainder of the season.

1.3 Description of Process for Action

If making a determination that there is evidence of Exceptional Circumstances, the WG will with due promptness:

- Consider the severity of the Exceptional Circumstances (for example, how severely "out of bounds" are the recent survey results or recruitment estimates).
- Follow the principles for action (see examples below).
- Formulate advice on the action required (this could include an immediate change in TAC, a review of the OMP, the relatively urgent collection of ancillary data, or conduct of analyses to be reviewed at a further WG meeting in the near future).
- Report to the Chief Director Research, DAFF that Exceptional Circumstances exist and provide advice on the action to take.

The Chief Director Research, DAFF, will:

- Consider the advice from the WG.
- Decide on the action to take, or recommendations to make to his/her principals.

Examples of 'Principles for Action'

If the risk is to the resource, or to dependent or related components of the ecosystem, principles may be:

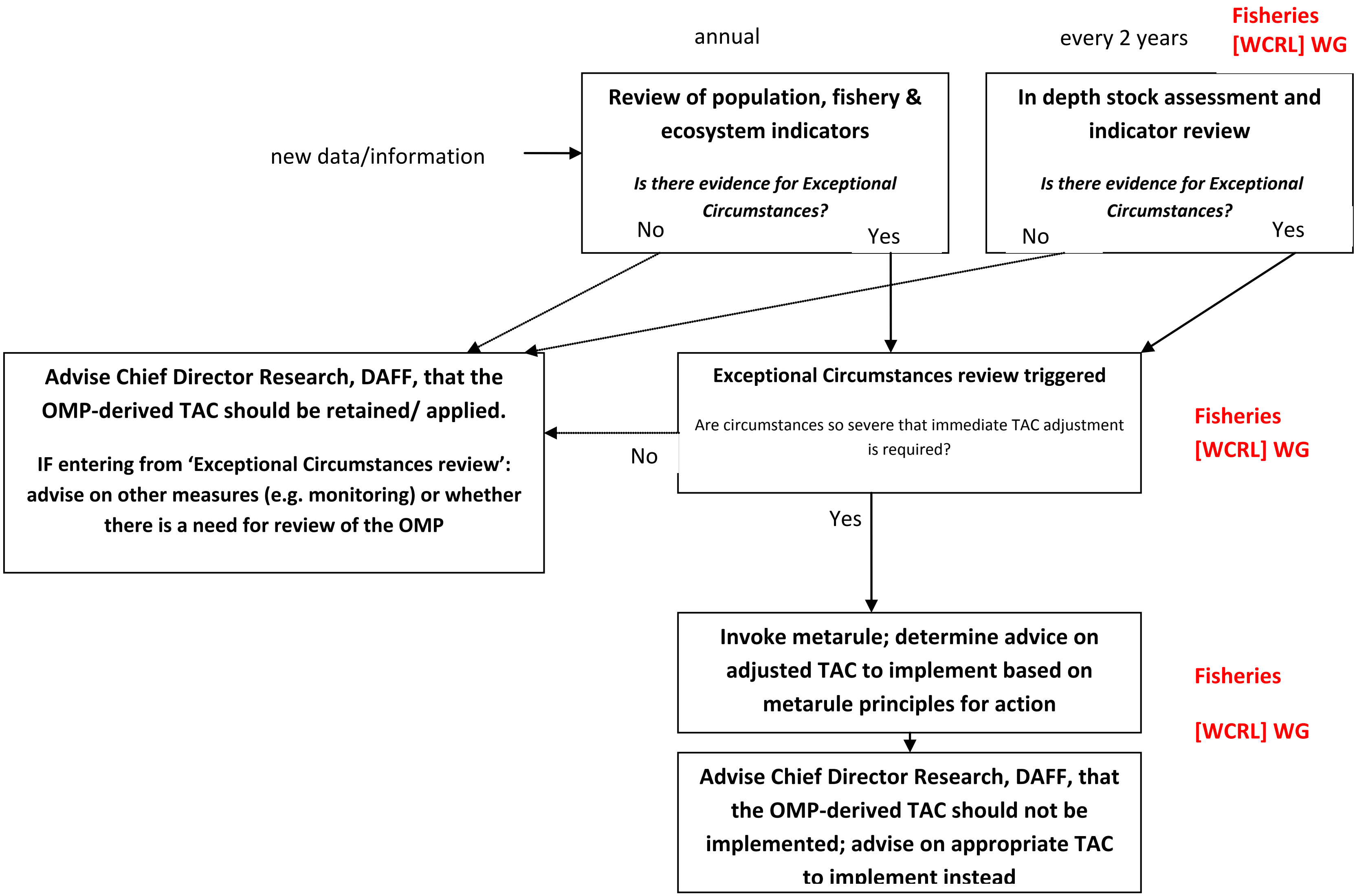
- The OMP-derived TAC should be an upper bound.
- Action should be at least an x% decrease in the TAC output by the OMP, depending on severity.

If the risk is to socio-economic opportunities within the fishery, principles may be:

- The OMP-derived TAC should be a minimum.
- Action should be at least a y% increase in the TAC output by the OMP, depending on severity.

For certain categories of Exceptional Circumstances, specific metarules may be developed and pre-agreed for implementation should the associated circumstances arise (for example, as has been the case for OMP's for the sardine-anchovy fishery where specific modified TAC algorithms come into play if abundance estimates from surveys fall below pre-specified thresholds). Where such development is possible, it is preferable that it be pursued.

Figure 1: Flowchart for Metarules Process



2. Regular OMP Review and Revision Process

The procedure for regular review and potential revision of the OMP is the process for updating and incorporating new data, new information and knowledge into the management procedure, including the operating models (OMs) used for testing the procedure. This process should happen on a relatively long time-scale to avoid jeopardising the performance of the OMP, but can be initiated at any time if the WG consider that there is sufficient reason for this, and that the effect of the revision would be substantial. During the revision process the OMP should still be used to generate TAC recommendations unless a metarule is invoked.

2.1 Description of Process for Regular Review (see Fig. 2)

Every year the WG will:

- Consider whether the procedure for Metarule Process has triggered a review/revision of the OMP. Note that if proposals by a WG Member or Observer, or DAFF Management, for an Exceptional Circumstances review include suggestions for an OMP review and possible revision, they must outline in writing the reasons why they consider this necessary, and must either indicate where the data or analyses are to be found supporting their proposed review, or must supply those data or analyses in advance of the WG meeting at which their proposal is to be considered. This includes the possibility of a suggested improvement in the manner in which the OMP calculates catch limitation recommendations; this would need to be motivated by reporting results for this amended OMP when subjected to the same set of trials as were used in the selection of the existing OMP, and arguing that improvements in anticipated performance were evident.

Every two years the WG will:

- Conduct an in depth stock assessment and review population, fishery and related ecosystem indicators, and any other relevant data or information on the population, fishery and ecosystem.
- On the basis of this, determine whether the assessment (or other) results are outside the ranges for which the OMP was tested (note that evaluation for Exceptional Circumstances would be carried out in parallel with this process; see procedures for the Metarule Process), and whether this is sufficient to trigger a review/revision of the OMP.
- Consider whether the procedure for the Metarule Process triggered a review / revision of the OMP.

Every four years since the last revision of the OMP the WG will:

- Review whether enough has been learnt to appreciably improve/change the operating models (OMs), or to improve the performance of the OMP, or to provide new advice on tuning level (chosen to aim to achieve management objectives).
- On the basis of this, determine whether the new information is sufficient to trigger a review/revision of the OMP.

In any year, IF the WG concludes that there is sufficient new information to trigger a review/revision of the OMP, the WG will:

- Outline the work plan and timeline (e.g. over a period of one year) envisaged for conducting a review.
- Report to the Chief Director Research, DAFF that a review/revision of the OMP is required, giving details of the proposed work plan and timeline.
- Advise the Chief Director Research, DAFF that the OMP can still be applied while the revision process is being completed (unless Exceptional Circumstances have been determined to apply and a metarule invoked).

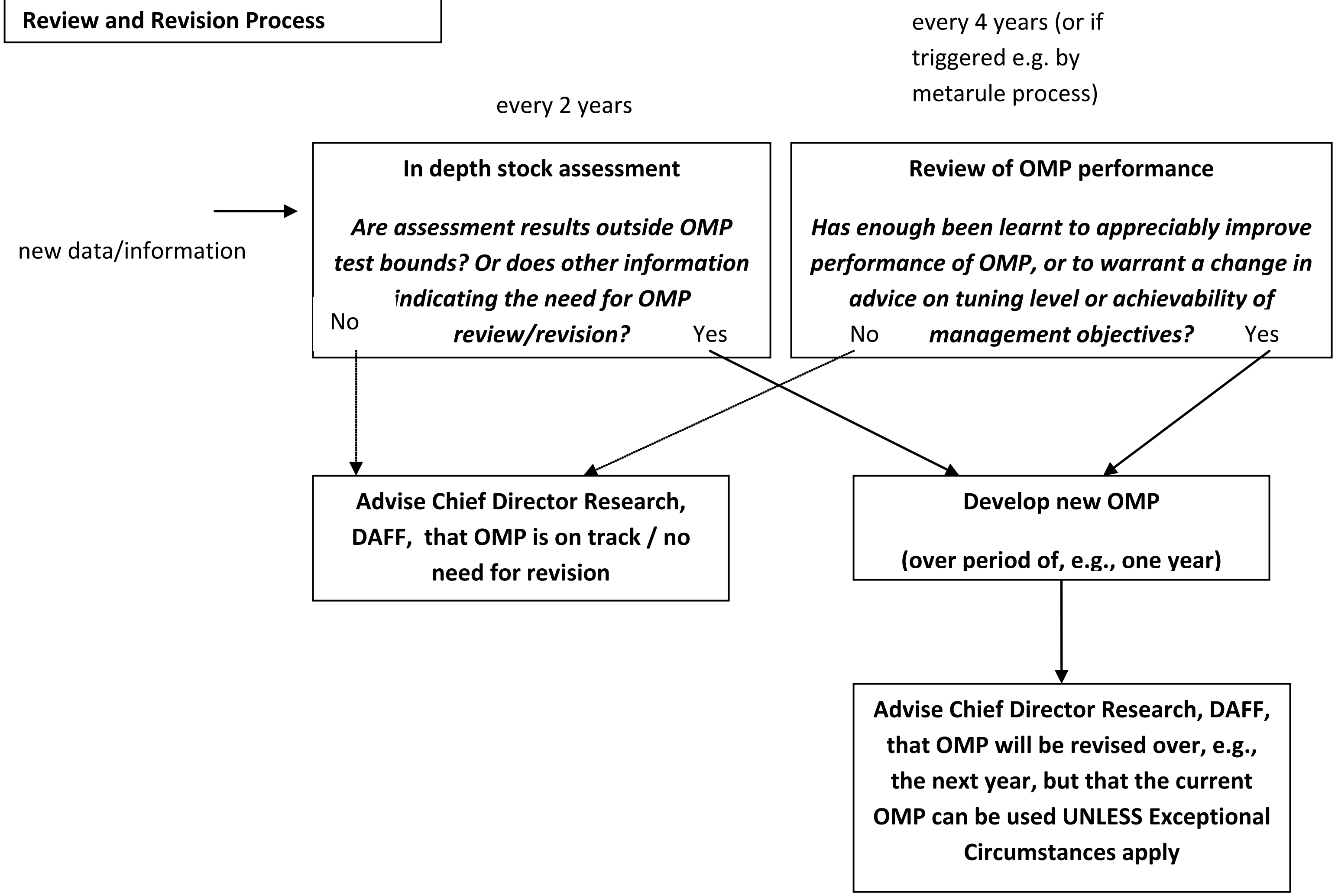
In any year, IF the WG concludes that there is no need to commence a review/revision of the OMP, the WG will:

- Report to the Chief Director Research, DAFF that a review/revision of the OMP is not yet required.

The Chief Director Research, DAFF will:

- Review the report from the WG.
- Decide whether to initiate the review/revision process.

Figure 2. Flowchart for Regular Review and Revision Process



Fisheries

[WCRL WG]