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

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**Summary**

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

**Introduction**

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

“OMP-2007 re-cast”

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

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

Area 1-2: 8.4 MT (30 MT)

Area 3-4: 1.3 MT (100 MT)

Area 5-6: 0 MT (40.25 MT)

Area 7: 526.8 MT (821.75 MT)

Area 8: 1670.6 MT (1565 MT)

Total: 2207.1 MT (2557 MT)

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

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

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

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

Area 1-2: 9.1 MT

Area 3-4: 27.3 MT

Area 5-6: 25.3 MT

Area 7: 0 MT

Area 8: 44.5 MT

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

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

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

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

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

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

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

1. **The combination of data across super-areas**

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

**Combined CPUE and FIMS indices:**

The “global” OMP requires a single index for each data source (somatic growth, trap CPUE, hoop CPUE and FIMS) for each season in the future. The last three of these are combined across super-areas as follows:

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



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

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



and the FIMS series



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

 (3)

where .

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

;

then:

 and (4)

 etc.

For FIMS, as above, but is used instead of  (again, the biomass weighted by the appropriate selectivity is used from the source specified below).

Since there will be a lack of certain data types for some super-areas, summations above are adjusted accordingly:

Traps A7 and A8 only

Hoops: A1-2, A3-4, A5-6 and A8 only

FIMS: A3-4, A5-6, A7 and A8 only.

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

**Combined somatic growth index (** $β\_{y}$)**:**

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

The procedure is to use similar weighting factors, e.g., as for trap and hoop CPUE (except that now weighting factors for all five super-areas are used). Note also the biomass relates to total male biomass above 70mm only.

Thus  (5)

where:

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

The assessments referenced above are taken to be the MARAM/OLRAC averaged RC1-like assessments conducted in 2006 (Johnston and Butterworth 2006), so that the biomasses above are all available and hence also the weighting factors. The table below lists these *w* values. [Note that the blanks indicate that data are not expected from that super-area for that gear type in the future, and hence such data are omitted from the OMP.]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |
| **A1-2** | - | 0.025 | - | 0.018 |
| **A3-4** | - | 0.234 | 0.157 | 0.176 |
| **A5-6** | - | 0.152 | 0.075 | 0.082 |
| **A7** | 0.400 | - | 0.188 | 0.229 |
| **A8** | 0.600 | 0.588 | 0.580 | 0.495 |

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

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

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

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

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

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

1. **OMP TAC setting rule**

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

 (6)

Where:

*wy* = 0.50 for all seasons;

 *p =* 0.5;

*f*1 = 0.40;

*f*2 = 0.40; and

 is the primary tuning parameter, which for “OMP-2007 re-cast” is 4560.

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

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

The choice of control parameter values *f*1 and*f*2 for the final term means a TRAP:HOOP:FIMS abundance index data relative weighting of 0.4:0.4:0.2.

##### Estimation of  and

The underlying approach is to fit a simple population model to available *CPUEtrap*, *CPUEhoop*, *FIMS* and somatic growth data to model the dynamics from 1992 to season *y*-1, the most recent season for which data are available, i.e.:

 (7)

where:

* =* population model biomass in season *Y;*

*GY* = annual “growth” of resource in season *Y,*

*CY* = annual commercial + recreational catch in season *Y[[2]](#footnote-2)*; and

*PY* = annual estimate of poaching for season *Y*.

 is a parameter estimated in fitting this model to the data.

Past catch data are given in Appendix 6.

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

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

 (8)

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

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

 (9)

where:

 is the trap CPUE for season *Y;*

 is the hoop CPUE for season *Y;*

*FIMSY* is the FIMS CPUE for season *Y;*

 is the trap catchability coefficient;

 is the hoop catchability coefficient;

*qFIMS* is the FIMS catchability coefficient;

; (10)

; (11)

; (12)

; (13)

; (14)

; and (15)

*n* = number of data points in the series referenced.

The parameters of the likelihood *L* estimated in the fitting process are  and *a.*

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

 (16)

where .

Thus, equation (9) becomes:

 (17)

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

A number of further modifications are made to the basic TAC algorithm of equation (1). Their aim is particularly to react to reduce catches sufficiently if especially poor resource signals are forthcoming. These are as follows.

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

A maximum TAC downward inter-annual constraint of 10% is assumed for the first two seasons (2007 and 2008). From 2009 onwards, this constraint is modified according to the value of the somatic growth rate index (), where  indicates the geometric mean of the somatic growth index  over the seasons in , as follows:



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

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

**ii) Response to somatic growth changes**

If  (where , then the response to the annual average somatic growth rate index in the basic TAC algorithm (equation (5)) is given by , with  set at 1 so that this term varies linearly with recent somatic growth rate.

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

 $\rightarrow $ (18)

For values and  (which were selected for preferred OMP performance), the following somatic growth rate response function then applies:



iii) **Capping of input data**

A maximum inter-annual increase in any one of the input indices from each super-area (prior to the combining over all five super-areas into a single index for input into the OMP) is imposed. The reason relates to the fact that for some simulations used in the OMP testing process, due to very large variances ( values) being used to generate the “real” data for use in the OMP, some very large CPUE or FIMS values occurred. To avoid the associated high output variance which could result, a cap was imposed in the simulations, and so is similarly imposed on real data for any input index value (from any of the 5 super-areas). Thus any value which is greater then 2.5 times the arithmetic average of the previous 5 years’ values is capped at that average value multiplied by 2.5.

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

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

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

 initially (i.e. for the 2007 season)

If  then 

If  then  (19)

If  MT then MT

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

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

Area 1-2 = 2%

Area 3-4 = 12.5%

Area 5-6 = 12.5% (20)

Area 7 = 4%

Area 8 = 69%

The remaining (commercial) TAC () (adjusted if necessary at this stage to conform to inter-annual TAC change constraints) must then be split into super-area allocations. First the nearshore allocations are calculated, and then subtracted as indicated below.

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

 initially (i.e. for the 2007 season)

If  then 

If  then  (21)

If  MT then MT.

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

Area 1-2  = 5.36% of 

Area 3-4  = 16.07% of 

Area 5-6  = 7.14% of  (22)

Area 7  = 0% of 

Area 8  = 71.43% of 

Finally the TAC allocation to offshore rights holders in each super-area A, , is divided between super-areas A3-4, A7 and A8 as follows:

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

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

 (assuming three series), (23)

where:

 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+*slopeA*) for that super-area, giving a new set of commercial allocations by super-area, which will not necessarily total to the new overall offshore commercial TAC ($TAC\_{y}^{off})$ for the super-areas concerned. If the allocations do not total to that offshore commercial TAC, simply scale them all by the same proportion so that they do total to match that offshore commercial TAC.

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

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

 . (24)

**Summary of the order of the TAC calculations**

1. The OMP generates the global (all super-areas combined) commercial (offshore+nearshore rights holders)+recreational TAC =  recommendation.
2. Check for inter-annual TAC constraint violations (at a global level) and adjust  if necessary.
3. Remove the total recreational take component (which would then be split into super-areas as per the specified proportions for subsequent computations in any simulation testing):

 .

1. Re-check that the remaining commercial (offshore+nearshore rights holders)  does not violate inter-annual TAC constraints; if it does, adjust it to the bound concerned.
2. Calculate the total nearshore TAC, .
3. Split the total nearshore TAC component into super-areas according to fixed proportions – note no nearshore TAC allocation for super-area A7. This gives:
 . Note $NSQ\_{y}^{A7}$=0.
4. Remove the total nearshore TAC component from the total commercial TAC to give the amount to be split into offshore TAC for super-areas A3-4, A7 and A8 (note no offshore TAC allocations for A1-2 and A5-6), i.e.:

 .

1. Split the offshore TAC into A3-4, A7 and A8 (using the slopes method above– this gives initial ). Note that  and  are both equal to zero.
2. Transfer 5% of offshore TAC from A8 into A3-4 (20%) and A7 (80%):

 



.

1. The final commercial TAC allocations are then:



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

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

**References**

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

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

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

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

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

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

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

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

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

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

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1. Introduction

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

2. Area classification

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

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

The classification is shown in Table A2.1.

3. Data

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

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

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

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

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

* Model 1 includes data from all areas *except* Port Nolloth and Hondeklip Baai (Areas 1 & 2.) The slope parameter  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 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 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:

 (A2.1)

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

The moult season of release and recapture are defined as:

 (A2.2)

where:

 is the date of release for lobster *i*

 is the date of recapture for lobster *i.*

* 1. 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  and standard deviation , truncated at the beginning and end of the season. The parameters  and  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:



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:



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



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:

 (A2.3)

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

 (A2.4)

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

 . (A2.5)

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

  (A2.6)

It is easily verified that  (A2.7)

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

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

 (A2.8)

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

  (A2.9)

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

 (A2.10)

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

 . (A2.11)

* 1. The growth model for a single moult.

 (A2.12)

where:

 is an area factor for sub-area *ai,* ;

 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*’;

 is a slope parameter;

 is the interaction effect of area *ai* and moult season *m*, treated as a random effect, assumed to be normally distributed about zero with variance ;

 is the size of the lobster in moulting season  prior to moulting;

 is growth realized by lobster *i* in moulting season ; 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;

 is an intercept parameter;

 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 ; and

 is measurement error, assumed to be normally distributed with a variance of . 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*):

 (A2.13)

Successive increments in growth are represented as follows:

 (A2.14)

which can be rewritten as:

 (A2.15)

The latter simplifies to:

 (A2.16)

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

 (A2.17)

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

* Error term for 1 moult: 
* Error term for 2 moults: 
* Error term for 3 moults: 

The last expression indicates a general rule for the propagation of the error in terms of the  and  values. If the model errors  for successive moults are i.i.d. with variance  then the error terms are also normally distributed with variances given by:

* Variance of error term for 1 moult: 
* Variance of error term for 2 moults: 
* Variance of error term for 3 moults: 

Let  be the variance of the cumulative growth . If measurement error has a variance  then this must be included in . Let  be the growth that arises from three consecutive moults; then the variance in this cumulative growth would be:

 (A2.18)

The variance of the cumulative growth rate from n moults, is given as:

 (A2.19)

4.5 The likelihood function

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

Case A: 

Case B: 

Case C: 

Case D: . (A2.20)

The likelihood of the observed growth of , , is proportional to the sum of the four terms listed above:

 (A2.21)

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

 (A2.22)

The objective function is then given by:

*F* =  (A2.23)

where *d* is the number of active random effects, i.e. the number of area (*a*) and moult-season (*m*) combinations for which lobsters in the dataset are at large, and  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:

 (A2.24)

where:

 is the median area factor for sub-areas in the super-area;

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

 is the slope parameter.

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

The spatially disaggregated estimates are obtained as follows:

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

**Table A2.1 Area classification.**

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

**Appendix 3: Trap CPUE analyses for inputs to the OMP**

**Introduction**

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

**Basic data**

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

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

**The selection of the forms for the GLMs**

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

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

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

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

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

**Extension for future seasons to provide OMP input**

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

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

1. they will include co-variates as specified in Table A3.5, and calculate indices from the GLM outputs as indicated in Tables A3.6 and A3.7 (note that this means that values for past seasons shown in Table A3.8 will be updated slightly each season);
2. 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;
3. the procedure described above to interpolate any missing values for the season-month interaction cells will be as described above;
4. the procedure for excluding outliers (related to the studentized residuals) will be as specific above; and
5. there must be more than five data points for estimation of a season-month interaction term to be attempted within the GLM.

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



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



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



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



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

|  |  |
| --- | --- |
| **Super-area** | **Model** |
| 3+4 | *ln*CPUE=α+βseason+γmonth+κArea+(season×month)+(season×Area)+ε |
| 5+6 | *ln*CPUE=α+βseason+γmonth+(season×month)+ε |
| 7 | *ln*CPUE=α+βseason+γmonth+(season×month)+ε |
| 8 | *ln*CPUE=α+βseason+γmonth+(season×month)+ε |

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

|  |  |
| --- | --- |
| **Super-area** | **Equation** |
| **Area 3+4** |  |
| **Area 5+6** |  |
| **Area 7** |  |
| **Area 8** |  |

**Table A3.7: Area sizes (km2) applied to Areas 3, 4 and 8. The sizes of Areas 3 and 4 include Marine Protected Areas (which was not the case before for the area-aggregated analyses). It is assumed that the area size for Area 8 increased in a linear fashion over the period 1987 – 1995 so that the area East of Hangklip could be incorporated for the period when lobsters moved into this area.**

|  |  |  |
| --- | --- | --- |
| Area | Season | Area size (km2) |
| 3 | n/a | 1141 |
| 4 | n/a | 2375 |
| 8 | ≤ 1986 | 2621 |
|  | 1987 | 2761 |
|  | 1988 | 2901 |
|  | 1989 | 3042 |
|  | 1990 | 3182 |
|  | 1991 | 3322 |
|  | 1992 | 3462 |
|  | 1993 | 3603 |
|  | 1994 | 3743 |
|  | ≥ 1995 | 3883 |

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

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

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

1. **Area 3+4**



1. **Area 5+6**



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

1. **Area 7**



1. **Area 8**



**Annexure 3A**

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

**A. General exclusions (across all Areas)**

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

**B. Super-area specific exclusions**

**Area 3+4**

1. All records not pertaining to Area 3 or 4

2. Season > 2001 (patchy data)

3. June and July (patchy data)

4. February 1982 (*n*≤5)

5. April 1996 - 1998 (*n*≤5)

**Area 5+6**

1. All records not pertaining to Area 5 or 6

2. Season > 1997 (patchy data)

3. June and July (patchy data)

4. March 1981 (*n*≤5)

5. March 1987 (*n*≤5)

6. April 1987 (*n*≤5)

7. April 1993 (*n*≤5)

8. May 1993 (*n*≤5)

9. May 1994 (*n*≤5)

**Area 7**

1. All records not pertaining to Area 7

2. July-Sept (patchy data)

3. June 1986 (*n*≤5)

4. June 1990 (*n*≤5)

5. June 1991 (*n*≤5)

6. April 1992 (*n*≤5)

7. April 1995 (*n*≤5)

8. June 1996 (*n*≤5)

9. June 1997 (*n*≤5)

**Area 8**

1. All records not pertaining to Area 8

2. Season < 1985

3. July 1986

4. November in seasons 1992-1995

5. December 1996

6. December 2000

7. December 2001

8. November 2002

**Appendix 4: Hoopnet CPUE analyses for inputs to the OMP**

**Introduction**

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

**Basic data**

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

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

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

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

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

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

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

**The selection of the forms for the GLMM and GLMs**

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

.

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

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

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

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

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

**Extension for future seasons to provide OMP input**

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

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

1. they will include co-variates as specified in Table A4.5, and calculate indices from the GLM outputs as indicated in Tables A4.6 and A4.7 (note that this means that values for past seasons shown in Table A4.8 will be updated slightly each season);
2. 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;
3. the procedure described above to interpolate any missing values for the season-month interaction cells will be as described above;
4. the procedure for excluding outliers (related to the studentized residuals) will be as specific above; and
5. there must be more than five data points for estimation of a season-month interaction term to be attempted within the GLM.

**Reference**

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

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



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

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

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



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



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



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



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

|  |  |  |  |
| --- | --- | --- | --- |
| **Super-area** | **Model type** | **Data source** | **Model** |
| 1-2 | GLMM | Bakkies + Deckboats | *ln*CPUE=α+βseason+γmonth+τfishing type+(season×month)+ε |
| 3-4 | GLM | Bakkies+Deckboats | *ln*CPUE=α+βseason+γmonth+τfishing type+(season×month)+ε |
| 5-6 | GLM | Bakkies | *ln*CPUE=α+βseason+γmonth+κArea+(season×month)+(season×Area)+(month×Area)+ε |
| 8 | GLM | Bakkies | *ln*CPUE=α+βseason+γmonth+(season×month)+ε |

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

|  |  |
| --- | --- |
| **Super-area** | **Equation** |
| **Area 1-2** |  |
| **Area 3-4** |  |
| **Area 5-6** |  |
| **Area 8** |  |

**Table A4.9: Area sizes (km2) applied to Areas 3-7 respectively. Note that these sizes include Marine Protected Areas in the calculation of the size of the habitat area (which was not the case in previous area-aggregated analyses).**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Area 3** | **Area 4** | **Area 5** | **Area 6** | **Area 7** |
| 1141 | 2375 | 561 | 834 | 2851 |

**Table A4.10: Area sizes (km2) applied to Area 8. It is assumed that the area size for Area 8 increased in a linear fashion over the period 1987 – 1995 so that the area East of Hangklip could be incorporated into this area.**

|  |  |
| --- | --- |
| Season | Area size (km2) |
| ≤ 1986 | 2621 |
| 1987 | 2761 |
| 1988 | 2901 |
| 1989 | 3042 |
| 1990 | 3182 |
| 1991 | 3322 |
| 1992 | 3462 |
| 1993 | 3603 |
| 1994 | 3743 |
| ≥ 1995 | 3883 |

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

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

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

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

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



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

1. **Area 3-4 (bakkies+deckboats)**



1. **Area 5-6 (bakkies)**



1. **Area 8 (bakkies)**



**Annexure 4A**

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

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

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

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

4. April 1996 (*n*≤5)

5. May 1999 (*n*≤5)

6. November 2002 (*n*≤5)

**Area 5-6**

1. All records not pertaining to Area 5 or 6

2. June (patchy data)

3. Area = 6 and season = 1999 (small sample size – problematic in season/area interaction)

4. Season 1987 (patchy data)

5. Season 2001 (patchy data)

6. February 1988 (*n*≤5)

7. May 1989 (*n*≤5)

8. May 1990 (*n*≤5)

9. April 1997 (*n*≤5)

**Area 8**

1. All records not pertaining to Area 8

2. August and September (patchy data)

3. Season 1989 (patchy data)

4. May and June 1986 (*n*≤5)

5. June 1987 (*n*≤5)

6. November 1987 (*n*≤5)

7. November 1988 (*n*≤5)

8. November and December 1990 (*n*≤5)

9. April and May 1991 (*n*≤5)

10. July 1994 (*n*≤5)

11. July 2000 (*n*≤5)

12. November 2002 (*n*≤5)

13. November 2003 (*n*≤5)

14. November 2004 (*n*≤5)

15. December 2004 (*n*≤5)

16. July 2004 (*n*≤5)

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

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

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

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# Introduction

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

**Data**

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

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

#### Methodology

**Relative Abundance Indices by Zone**

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

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

, (A5.1)

where

 is the weighted mean CPUE in year *y* for stratum *z* and leg *ℓ*;

 is the average number of lobsters caught per trap set at station *i* in stratum *z* and year *y* and leg *ℓ*;

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

 *zs* 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:

 , (A5.2)

where

  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* (), for which the estimate is given by:

,

where  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, , 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:

, (A5.3)

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

  is the proportion that the area surveyed in stratum *z* comprises of the total area sampled, i.e. , where *Az* 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:

 , (A5.4)

where  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 () for these two records were estimated as the average of the observed (and computable) standard deviations or CVs for that stratum. The choice between using the average of standard deviations or the average of the CVs was based on which measure was more constant over the years.

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

**Comparison with previous FIMS indices**

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

, (A5.5)

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

# Results

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

**References**

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

van Zyl, D., Auerswald, L. and Merkle, D. 2009. FIMS area calculations, station numbers,

category, repeats and position. Marine and Coastal Management Document MCM/2009/JUL/SWG/WCRL/04.

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

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

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

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

\* Based on only one leg of the survey.

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

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

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

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

**Appendix 6: Catch data used in the OMP**

**Table A6.1**: Total (all super-areas combined) commercial, recreational, near-shore

 and interim-relief catch estimates (all in MT).

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

**Data sources**

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

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

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

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

1. The convention used in this document is that the “2007 season” refers to the season commencing in 2007 and concluding in 2008, i.e. to 2007/8. [↑](#footnote-ref-1)
2. Note that an extra 175.06 MT is added for the 2007 season to take into account the interim relief tonnage taken. Interim relief estimates for 2007+ years will also be taken into account in this manner. [↑](#footnote-ref-2)