A record of the generation of data used in the 2012 sardine and anchovy assessments

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The data to which the South African anchovy and sardine assessments are tuned are not raw data. Some of the data have already been subjected to a number of analyses and refinements. These associated calculations are often done "behind the scenes" and their details are seldom recorded. This lack of record can result in a discontinuity in the method used to calculate data for subsequent assessments, particularly if assumptions made in the calculations are not documented and/or a new person becomes responsible for developing the data to be used for input to the assessment. This document serves to record the generation from the raw data of the data used in the anchovy and sardine assessments carried out in 2012. It is an update of de Moor *et al*. 2011 to include data from November 2010 to October 2011 and new proportions and weights-at-age for anchovy. All files referred to below are available from the first author.

Anchovy Commercial Data

Monthly Raised Length Frequencies (RLFs)

Monthly raised length frequencies were constructed for the anchovy landings using the method in Appendix A. Although it is possible to split the RLFs by area from 1987, as the assessment will be run for a single stock in a single area, RLFs for a single area only are considered.

In 7 months no length frequencies were available although there were landings. In these cases the length frequencies of former months were used to estimate a raised length frequency as follows:

$$RLF_{y,missing,l} = RLF_{y,previous,l} \times Tonnage_{y,missing} / Tonnage_{y,previous}$$

The "former" month used in this estimation is listed in the below table.

Year	Month for which length frequency was missing	Tonnage landed in missing month	Area in which landings occurred	Month from which length frequency was used	Tonnage landed in this used month
1984	October	22 878t	Western	July 1984	18 193t
1984	November	7 281t	Western	July 1984	18 193t

The RLFs by month from 1984 to 1986 and also by area from 1987 to 2010 are stored in *Anchovy RLFs with Cut-Off Lengths.xls*.

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Splitting Juvenile and Adult Catch

Cunningham and Butterworth 2007 proposed the use of the following cut-off lengths for each month to calculate the number of juveniles and adults:

Month	Cut-off length
January	7cm
February	8cm
March	9cm
April	9.5cm
May	10cm
June	10.5cm
July	10.5cm
August	10.5cm
September	10.5cm
October	10.5cm
November	5cm
December	6cm

However, the cut-off length used to calculate the number of recruits from the recruit survey differs on an annual basis, ranging between 9.5 and 11.5cm. In only 8 years do the above cut-off lengths for recruits in the commercial catch match that used to calculate the number of recruits surveyed. These cut-off lengths have been based on the length frequency as measured during the survey. To avoid a mismatch between the cut-off length used to calculate the recruits caught prior to the survey (used in the model to predict the number of recruits at the time of the survey) and that used to calculate the recruits observed during the survey, the above table of cut-off lengths was adjusted for certain years as follows:

Month	Survey Month	Fixed cut-off length	Survey cut-off length	New Commercial cut-off lengths			
				April	May	June	July-Oct
1985	May	10cm	10.5cm	9.5cm	10.5cm	10.5cm	10.5cm
1986	June	10.5cm	10.5cm	9.5cm	10cm	10.5cm	10.5cm
1987	July	10.5cm	11cm	9.5cm	10cm	10.5cm	11cm
1988	June	10cm	11.5cm	9.5cm	10.5cm	11.5cm	11.5cm
1989	June	10cm	10.5cm	9.5cm	10cm	10.5cm	10.5cm
1990	June	10cm	10.5cm	9.5cm	10cm	10.5cm	10.5cm
1991	May	10cm	10.5cm	9.5cm	10.5cm	10.5cm	10.5cm
1992	May	10cm	10.5cm	9.5cm	10.5cm	10.5cm	10.5cm
1993	May	10cm	10.5cm	9.5cm	10.5cm	10.5cm	10.5cm
1994	May	10cm	9.5cm	9.5cm	9.5cm	10cm	10.5cm
1995	June	10cm	10.5cm	9.5cm	10cm	10.5cm	10.5cm
1996	July	10cm	10.5cm	9.5cm	10cm	10.5cm	10.5cm
1997	May	10cm	10cm	9.5cm	10cm	10.5cm	10.5cm
1998	May	10cm	10.5cm	9.5cm	10.5cm	10.5cm	10.5cm
1999	May	10cm	10cm	9.5cm	10cm	10.5cm	10.5cm

Month	**Survey Month**	**Fixed cut-off length**	**Survey cut-off length**	**New Commercial cut-off lengths**			
				April	**May**	**June**	**July-Oct**
2000	May	10cm	9.5cm	9.5cm	9.5cm	10cm	10.5cm
2001	May	10cm	9cm	9cm	9cm	10cm	10.5cm
2002	May	10cm	11cm	10cm	11cm	11cm	11cm
2003	May	10cm	10cm	9.5cm	10cm	10.5cm	10.5cm
2004	May	10cm	11cm	10cm	11cm	11cm	11cm
2005	May	10cm	9.5cm	9.5cm	9.5cm	10cm	10.5cm
2006	May	10cm	9.5cm	9.5cm	9.5cm	10cm	10.5cm
2007	May	10cm	9.5cm	9.5cm	9.5cm	10cm	10.5cm
2008	May	10cm	9.5cm	9.5cm	9.5cm	10cm	10.5cm
2009	May	10cm	10.5cm	9.5cm	10.5cm	10.5cm	10.5cm
2010	May	10cm	11cm	10cm	11cm	11cm	11cm
2011	May	10cm	11cm	10cm	11cm	11cm	11cm

Monthly anchovy catch numbers are available for 1981 to 1983 (De Oliveria pers. comm.) but no RLFs are available for these months. These data are not used in the assessment.

The resulting monthly catch numbers of juveniles and adults, summed over all areas, are stored in *Anchovy Commercial Catch.xls*. The annual juvenile and adult anchovy catches for year *y* are calculated as the sum over all months from November *y*-1 to October *y*. The annual juvenile and adult anchovy catch data are given in Table 1 and stored in *Anchovy Commercial Catch.xls*.

<u>Catch Weight</u>

The data available for these calculations include the number of fish in length class *l* in month *m* in area *a*, $N_{l,m,a}$, (used above) and the observed tonnage in month *m* in area *a*, $ObsT_{m,a}$ from 1984 to 2011. These data are recorded in *Anchovy RLFs with Cut-Off Lengths.xls*. The length-weight relationship used is (Lynne Shannon pers. comm. using 1990-1996 data):

$mass = 0.00750 \times L_c^{3.110}$, where mass is in grams and length in centimetres.

Expected mass by length class, area and month is calculated as: $EM_{l,m,a} = 0.0075 \times l_{mid}^{3.110} \times N_{l,m,a}$

where l_{mid} is the mid-point of the length class considered.

Adjusted mass by length class, area and month is calculated as: $AM_{l,m,a} = \dfrac{EM_{l,m,a}}{\sum_l EM_{l,m,a}} \times ObsT_{m,a}$

Average monthly adjusted mass by length class, area and month is calculated as:

$$\overline{AM}_{l,m,a} = \frac{AM_{l,m,a}}{N_{l,m,a}} = \frac{\dfrac{EM_{l,m,a}}{\sum_l EM_{l,m,a}} \times ObsT_{m,a}}{N_{l,m,a}}$$

Average juvenile mass by month for the total area is calculated as: $M_m^{juv} = \dfrac{\sum_a \sum_{l<cutoff} \overline{AM}_{l,m,a} \times N_{l,m,a}}{\sum_a \sum_{l<cutoff} N_{l,m,a}}$

Average adult mass by month for the total area is calculated as: $M_m^{ad} = \dfrac{\sum_a \sum_{l\geq cutoff} \overline{AM}_{l,m,a} \times N_{l,m,a}}{\sum_a \sum_{l\geq cutoff} N_{l,m,a}}$

A check is performed on the calculations such that:

$$M_m^{juv} \times \sum_a \sum_{l<cutoff} N_{l,m,a} + M_m^{ad} \times \sum_a \sum_{l\geq cutoff} N_{l,m,a} = \sum_a ObsT_{m,a} \; .$$

The above calculations and average juvenile and adult anchovy catch mass by month are stored in *Anchovy RLFs with Cut-Off Lengths.xls*.

The annual average juvenile and anchovy catch mass are calculated using a weighted average: $\dfrac{\sum_m M_m^{juv} \times N_m^{juv}}{\sum_m N_m^{juv}}$ and $\dfrac{\sum_m M_m^{ad} \times N_m^{ad}}{\sum_m N_m^{ad}}$, where N_m^{juv} and N_m^{ad} are the monthly juvenile and adult catch-at-age reported in Table 1. These sums are taken over the months November *y*-1 to October *y*, except for 1984 when the sum is from January to October 1984. The annual values are given in Table 1 and stored in *Anchovy Commercial Catch.xls*.

Between 1981 and 1983 there were no data to calculate catch weights-at-age as above.

Juvenile catch prior to the survey

RLFs were also calculated from the first of the month in which the annual recruit survey took place to the day before the commencement of the survey using the method in Appendix A. Inspector data (which include samples for species split) are required to do this (see Appendix A), but were not available in 1985 and 1986. Daily skippers' estimates of tonnage landed were, however, available for these years. Although the total tonnage landed in May 1985 and June 1986 was estimated by the skippers to be different to that arising from the source data, it was assumed that the proportion of catch taken before the survey compared to the whole month was the same between the skippers' estimates and the source data. Thus RLFs for 1-19 May 1985 and

1-9 June 1986 were calculated as follows: $N_{l,partmonth,a} = N_{l,fullmonth,a} \times SkipperT_{partmonth} \big/ SkipperT_{fullmonth}$, using the data in the below table.

	Days for which catch is required	Catch for the month (tons)	Skipper estimated catch for the month (tons)	Skipper estimated catch prior to the survey (tons)
May 1985	1-19th	74245	77174	48396
June 1986	1-9th	64662	68189	10338

The cut-off length method described on page 2 was applied to calculate the number of juveniles landed in the month prior to the commencement of the survey. The associated average juvenile catch weight was also calculated using the method detailed on pages 2-3. The total juvenile catch prior to the survey was then summed over all months from November *y*-1 to the day prior to the commencement of the survey. The average juvenile mass in this catch was calculated as a weighted average, taking the number of juveniles caught in each month into account. These data are given in Table 2 and are available together with the necessary calculations in *Anchovy RLFs with Cut-Off Lengths.xls* and *Survey Data.xls*.

Sardine Commercial Data

Monthly raised length frequencies were constructed for the sardine landings using the method in Appendix A. From 1987, these have been split by area (east and west of Cape Agulhas) and the sardine bycatch with anchovy has been extracted separately from the directed sardine catch and sardine bycatch with redeye. Note that these sardine bycatch with anchovy RLFs have been recorded according to the sample allocation rule (>50% anchovy by mass in the landing), whereas the bycatch recorded in Sybase is exactly according to that reported by the scale monitors. The latter should ideally be according to PWG-agreed categorization charts (Anon. 2004), though in practice this categorization has not been applied rigorously. Small amounts of sardine bycatch with anchovy (totalling 20.9t) were recorded east of Cape Agulhas in 1992, 2007, 2008, 2010 and 2011. In the two stock hypothesis this is assumed to be taken west of Cape Agulhas with the remainder of the anchovy bycatch.

These sardine bycatch with anchovy data are split between juvenile (0-year old) and adult catch as follows:

Let $N_{y,m,l}$ denote the number of fish in length class *l* landed as bycatch with anchovy in month *m* of year *y*.

Juvenile sardine bycatch with anchovy landed in month *m* of year *y* is taken to be all sardine below a given cut-off length, i.e.

$$C_{y,m,0} = \sum_{l=l\min}^{<lcut(y,m)} N_{y,m,l}$$

Adult sardine bycatch with anchovy of length *l* landed in month *m* of year *y* , are all assumed to be 1 year olds, and are taken to be:

$$C_{y,m,1} = \sum_{l=lcut(y,m)}^{l\max} N_{y,m,l}$$

The directed sardine and sardine bycatch with redeye length frequencies are used directly in the assessment.

The cut-off length, $lcut(y,m)$, taken to apply to May and June was set at that used during the recruit survey, which is based on a modal progression analysis (Coetzee and Merkle 2007, given in Table 2). The cut-off length was decreased for months from May back to November, and increased from June through to October. This was done by considering the November survey length frequencies, both back from May to November of the previous year and forward to November of the current year. A faster growth rate was assumed in the earlier months:

Month	Number of length classes greater or less than the recruit survey cut-off length
November-December	-12 (-6cm)
January-February	-6 (-3cm)
March-April	-2 (-1cm)
May-June	0
July-August	+2 (+1cm)
September-October	+3 (+1.5cm)

This resulted in the following monthly cut-off lengths:

	October (y-1) to November (y)												
Month	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Nov-Dec	9.5	9.5	9.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	9.0	8.0
Jan-Feb	12.5	12.5	12.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	12.0	11.0
Mar-Apr	14.5	14.5	14.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.0	13.0
May-Jun	15.5	15.5	15.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	15.0	14.0
Jul-Aug	16.5	16.5	16.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	16.0	15.0
Sep-Oct	17.0	17.0	16.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	16.5	15.5

	October (y-1) to November (y)													
Month	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Nov-Dec	8.0	11.0	11.0	6.0	10.0	10.0	8.0	7.5	9.0	6.5	4.5	6.5	7.5	7.5
Jan-Feb	11.0	14.0	14.0	9.0	13.0	13.0	11.0	10.5	12.0	9.5	7.5	9.5	10.5	10.5
Mar-Apr	13.0	16.0	16.0	11.0	15.0	15.0	13.0	12.5	14.0	11.5	9.5	11.5	12.5	12.5
May-Jun	14.0	17.0	17.0	12.0	16.0	16.0	14.0	13.5	15.0	12.5	10.5	12.5	13.5	13.5
Jul-Aug	15.0	18.0	18.0	13.0	17.0	17.0	15.0	14.5	16.0	13.5	11.5	13.5	14.5	14.5
Sep-Oct	15.5	19.0	19.0	13.5	17.5	17.5	15.5	15.0	16.5	14.0	12.0	14.0	15.0	15.0

A cut-off length of 15.5cm was assumed for May/June 1984, corresponding to both the former default cut-off length and to that of 1985 with similar November 1+ abundances having been recorded in 1984 and 1985.

These numbers-at-length in the commercial catch, summarised as above are stored in *Sardine RLFs by area ANCHOVY BYCATCH FISHERY.xlsx* and *Sardine RLFs by area DIRECTED AND REDEYE BYCATCH FISHERY.xlsx*. The tonnages landed each month were provided with the RLFs from 1987 onwards. For 1984 to 1986 the monthly tonnages landed were obtained from RLF data provided for the assessment in 2004. For calculation purposes, these 1984 to 1986 catch data are all treated as directed and redeye bycatch.

For the single stock hypothesis, the catch tonnage and RLFs by month are assumed to be equal to the combined catch tonnage east and west of Cape Agulhas[1].

The annual commercial catch tonnages are given in Table 3.

ALKs for sardine commercial catch for some months each year from 1984 to 1999 were derived by Michael Kerstan (De Oliveria 2003). Due to inconsistencies between the ALKs from Michael Kerstan and those of Deon Durholtz and Cynthia Mtengwane, these ALKs have not been used in the assessments. Selected monthly ALKs for sardine commercial catch between 2004 and 2009 have been derived by Cynthia Mtengwane. The use of these data to calculate quarterly proportions-at-age in the commercial catch for use in the assessment has, however, been discouraged (see below for further details).

<u>Juvenile catch prior to the survey</u>

As catch is modelled quarterly, the observed sardine juvenile catch prior to the survey is required only from 1 May to the day before the survey commenced. This was calculated from the RLFs of landings between 1 May and the day before the commencement of the survey (totalled over all catches). The cut-off lengths used to calculate the recruit survey biomass, also used to calculate the recruit catch in May and June (see above) were applied. As for anchovy, inspector data were not available in 1985 and 1986. Daily skippers' estimates of tonnage landed were, however, available for these years. Although the total tonnage landed in May 1985 and June 1986 was estimated by the skippers to be different to that arising from the source data, it was assumed that the proportion of catch taken before the survey compared to the whole month was the same between the skippers' estimates and the source data. Thus RLFs for 1-19 May 1985 and 1-9 June 1986 were calculated as follows:

$N_{l,partmonth,a} = N_{l,fullmonth,a} \times SkipperT_{partmonth} / SkipperT_{fullmonth}$, using the data in the below table.

	Days for which catch is required	Catch for the month (tons)	Skipper estimated catch for the month (tons)	Skipper estimated catch prior to the survey (tons)
May 1985	1-19th	3274	479	205
June 1986	1-9th	4042	970	609

These data are stored in *Sardine RLFs by area DIRECTED AND REDEYE BYCATCH FISHERY.xlsx* and given in Table 2.

[1] The LFs assigned to some trawls slightly east of Cape Agulhas would likely have been from Gansbaai landings in a single area scenario, but due to the split in catches at Cape Agulhas, a LF from Mossel Bay area would instead be used. The difference between such single area and two-area RLFs is assumed to be minor.

November Survey Data

The time series of total biomass estimates from the acoustic surveys in November each year has previously been updated to "uncapped" biomass estimates, using a new target strength expression and, in the case of sardine, taking attenuation into account (Coetzee *et al*. 2008, de Moor *et al.* 2008). For assessment purposes we assume this corresponds to the biomass of all fish aged 1 and above. The time series of biomass and associated CVs is given in Table 4 for sardine and anchovy. In addition daily egg production method (DEPM) estimates of adult anchovy biomass between 1984 and 1991 are available and given in Table 4 (De Oliveira 2003). For assessment purposes we assume this corresponds to spawning biomass.

These survey data are stored in *SurveyData.xls*, with finer details on the calibration of uncapped biomass from capped biomass in *SardineNovCalibration_FINAL.xls* and *AnchovyNovCalibration_FINAL.xls*.

Anchovy ALKs for the November surveys from 1992 to 1995 were derived by Prosch (De Oliveria 2003), and by Kerstan for 1990, 1992 to 1995 (unpublished data). The application of these data to length frequencies from November surveys in the other years from 1984 to 2011 to calculate a proportion-at-age 1 would ignore the impact of inter-annual variation in recruitment on age-length keys. de Moor and Butterworth (2012) have devised a new time series of proportion-at-age 1 by fitting a model of the estimated age 1 and 2+ length frequencies to the November survey length frequencies. An alternative time series was also estimated assuming time-invariant variability about the mean length at age 1. These time series (of medians of the marginal posterior distributions calculated by de Moor and Butterworth (2012)) are given in Table 5 and stored in *PropAge1_MCMC results.xlsx*. A time series of weights-at-age 1 and 2+ in the November survey was calculated using these estimated proportions at age as follows. The time-invariant length-weight relationship gives an average weight-at-age of:

$$\tilde{w}_{y,a}^{A} = \sum_{l} \frac{N_{y,l}^{A}}{\sum_{l} N_{y,l}^{A}} f^{A}(l_{mid})$$

$$f^{A}(l) = 0.00750 \times l^{3.110}$$

where $f^{A}(l)$ is the length-weight (in cm and grams) relationship used for anchovy (Lynne Shannon pers. comm. using 1990-1996 data) with l_{mid} denoting the midpoint of the length class l, and $N_{y,l}^{A}$ is the number of fish of length l in the November survey weighted length frequency in year y (taken to be the median of the marginal posterior distributions calculated by de Moor and Butterworth (2012)). This is then corrected for annual variation in growth rates by normalising by the survey estimate of biomass, i.e.

$$w_{y,a}^{A} = \tilde{w}_{y,a}^{A} \frac{B_{y}^{A}}{\sum_{l} N_{y,l}^{A} f^{A}(l_{mid})}$$

The time series of anchovy November survey weights-at-ages 1 and 2+ also given in Table 5 and stored in *Anchovy Nov WLF_average weight.xlsx*

Sardine ALKs for the November surveys derived by Deon Durholtz are available by area (east and west of Cape Agulhas) for 1993, 1994, 1996, 2001 - 2004 and 2006 - 2009. Cynthia Mtengwane has compiled sardine ALKs by area for the November surveys in 1993, 1994, 1996, 2001, 2003, 2004, 2006 - 2010. ALKs for the November surveys from 1984-1999 derived by Michael Kerstan are also available (De Oliveria 2003), but inconsistencies between these ALKs and those from Durholtz and Mtengwane restricted the use of ALKs from all readers. As Mtengwane has read some sardine commercial ALKs the use of her ALKs were chosen in preference to those derived by Durholtz. The International Review Panel Report for the 2011 International Fisheries Stock Assessment Workshop recommended not using of the ALKs to calculate (commercial and) survey proportions-at-age for use in the assessments (Smith *et al*. 2011). This recommendation was based on an inability to detect strong cohorts in the age data (which are known to be present through inference from the survey estimates of abundance) which may be due to problems with ageing and/or problems with the construction of the survey length-frequency data.

The average weight of sardine associated with the November surveys is given in Table 6 and stored in *Survey Data.xlsx*.

Recruit Survey Data

The time series of recruitment estimates from the acoustic surveys in May/June each year has previously been updated to “uncapped” estimates of biomass, using a new target strength expression and, in the case of sardine, taking attenuation into account (Coetzee *et al*. 2008, de Moor *et al*. 2008, and recently updated further). The time series of biomass and associated CVs is given in Table 7 for sardine and anchovy. The recruit numbers at the time of the survey were calculated by summing the number of fish smaller than a cut-off length in the weighted length frequency (as per Method 1 of Appendix B). The average recruit weight is calculated by applying a length-weight regression to the weighted length frequency. This mean weight is then adjusted by the difference between the two biomasses (Method 1 of Appendix B). This calculated biomass and average recruit weight were calculated in a separate database, using the uncapped density per interval from the new time series as input. The two biomass series are not identical due to the different methods of weighting used (the capping regression and calibration is unaffected by the different methods). A brief description of the two methods is given in Appendix B. Although not ideal, this difference has been narrowed from what has previously been used. This is a matter that needs to be addressed at some stage. In the assessments, the recruit numbers are used together with the CVs on recruit biomass.

These survey data are stored in *SurveyData.xls*, with finer details on the calibration of uncapped biomass from capped biomass in *SardineMayCalibration_Jul2011.xls* and *AnchovyMayCalibration_Jul2011.xls*.

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Table 1. Annual juvenile and adult anchovy catch (in billions) and mean catch weight (in grams). Annual data for year y consists of data from November y-1 to October y, as described in the text above.

	Annual anchovy catch number		Annual anchovy catch weight	
Year	**0 year olds**	**1 year olds**	**0 year olds**	**1 year olds**
1984	29.987537	9.416485	5.654	10.210
1985	33.371373	7.860243	5.744	11.225
1986	50.114319	6.250229	4.535	11.569
1987	30.206807	31.995000	6.895	12.255
1988	52.937734	17.038205	6.225	14.099
1989	19.137241	14.209377	6.392	12.324
1990	32.073406	1.128842	4.304	11.971
1991	25.051411	1.226593	5.550	9.794
1992	59.888922	7.809713	4.235	12.220
1993	32.142345	9.063604	4.157	11.274
1994	20.916611	5.796501	4.349	11.221
1995	39.863617	1.677212	4.036	9.491
1996	6.245386	1.364796	4.738	9.445
1997	11.868556	0.072043	5.008	13.424
1998	21.938896	0.704636	4.553	11.324
1999	34.803815	0.454625	4.991	11.293
2000	44.709797	3.412580	5.120	11.304
2001	54.329708	4.228331	4.557	8.949
2002	44.238443	1.839153	4.427	10.839
2003	62.448521	1.144999	3.880	11.795
2004	39.672506	1.150048	4.618	7.945
2005	31.523186	10.084982	5.670	10.261
2006	29.611774	1.384965	4.070	10.863
2007	47.756279	1.765222	4.848	11.197
2008	49.966639	4.824806	4.087	11.439
2009	34.725644	4.592258	4.163	7.974
2010	39.494059	3.479163	4.680	10.031
2011	23.569693	1.666248	4.243	11.799

Table 2. The date of the commencement of the annual recruit survey; juvenile anchovy catch (in billions) and mean catch weight of individual fish (in grams) from 1 November y-1 to the day before the annual recruit survey in year y; and juvenile sardine catch (in billions) from 1 May to the day before the annual recruit survey.

Year	Date of commence-ment of survey	Time of the recruit survey after 1 May	Cut-off length (cm) for anchovy juvenile catch in the month of the survey	Juvenile anchovy catch between 1 Nov and the start of the survey	Mean juvenile anchovy catch weight prior to the survey	Cut-off length (cm) for sardine juvenile catch	Juvenile sardine catch between 1 May and the start of the survey	
							West of Cape Agulhas	East of Cape Agulhas
1985	20-May	0.613	<10.5	12.286	4.781	<15.5	0.1641	0.0000
1986	10-Jun	1.300	<10.5	21.078	4.623	<15.5	0.3399	0.0000
1987	20-Jul	2.613	<11.0	14.325	7.849	<15.0	0.1911	0.0000
1988	27-Jun[2]	1.867	<11.5	13.416	4.447	<16.0	0.3179	0.0000
1989	08-Jun[3]	1.233	<10.5	12.459	5.840	<16.0	0.3679	0.0000
1990	22-Jun	1.700	<10.5	31.038	4.329	<16.0	0.7216	0.0000
1991	07-May	0.194	<10.5	12.484	5.220	<16.0	0.0078	0.0000
1992	13-May	0.387	<10.5	12.200	3.947	<16.0	0.0288	0.0000
1993	21-May	0.645	<10.5	1.471	5.551	<16.0	0.0473	0.0001
1994	05-May	0.129	<10.5	4.316	4.700	<16.0	0.0687	0.0000
1995	10-Jun	1.300	<10.5	12.433	5.665	<16.0	0.5808	0.0000
1996	05-Jun	1.133	<10.5	4.080	4.528	<15.0	0.3546	0.0000
1997	17-May	0.516	<10.0	0.163	6.241	<14.0	0.0358	0.0000
1998	20-May	0.613	<10.5	5.995	6.264	<14.0	0.4242	0.0000
1999	10-May	0.290	<10.0	1.772	5.056	<17.0	0.0252	0.0001
2000	15-May	0.452	<9.5	7.990	5.990	<17.0	0.0849	0.0001
2001	05-May	0.129	<9.0	4.908	5.347	<12.0	0.0003	0.0000
2002	05-May	0.129	<11.0	2.581	7.000	<16.0	0.0346	0.0000
2003	14-May	0.419	<10.0	3.023	4.990	<16.0	0.0864	0.0007
2004	08-May	0.226	<11.0	3.923	5.762	<14.0	0.0360	0.0000
2005	13-May	0.387	<9.5	3.821	6.550	<13.5	0.1007	0.0000
2006	19-May	0.581	<9.5	0.883	5.220	<15.0	0.0368	0.0001
2007	18 May	0.548	<9.5	5.824	5.626	<12.5	0.0507	0.0000
2008	21 May	0.645	<9.5	3.698	6.664	<10.5	0.1082	0.0000
2009	15 May	0.452	<10.5	7.398	3.440	<12.5	0.0317	0.0000
2010	27 May	0.839	<11.0	6.921	5.057	<13.5	0.2794	0.0017
2011	27 May	0.839	<11.0	5.781	5.030	<13.5	0.1979	0.0000

[2] The first station was on 27th June 1988, although the first acoustic interval was only logged after midnight, i.e. on 28th June 1988.

[3] The first station was on 8th June 1989, although the first acoustic interval was only logged after midnight, i.e. on 9th June 1989.

Table 3a. The monthly sardine commercial catch tonnage (in thousands of tons) landed as directed catch or bycatch with the redeye fishery, west of Cape Agulhas.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1984	1.980	6.802	4.975	6.520	5.114	1.361	0.010	0.000	0.000	0.261	0.131	0.000
1985	3.641	5.715	6.198	4.255	3.274	5.640	1.964	0.011	0.014	0.000	0.000	0.000
1986	1.310	7.319	8.638	3.539	2.714	4.042	2.855	0.162	0.060	0.000	0.000	0.000
1987	3.675	6.322	7.013	5.638	1.851	1.398	0.524	0.218	0.066	0.000	0.000	0.000
1988	1.824	5.312	2.739	5.892	3.904	4.159	2.624	1.323	0.353	0.208	0.912	0.657
1989	1.374	2.549	7.463	4.339	2.639	2.979	1.938	0.774	0.178	0.037	0.176	0.072
1990	3.017	6.014	7.676	6.569	9.338	4.825	3.587	5.148	1.715	0.695	0.344	0.428
1991	2.525	6.128	4.017	6.159	7.451	5.552	5.699	3.993	1.586	1.098	0.124	0.188
1992	0.781	5.147	5.595	2.331	1.967	7.055	2.877	5.347	6.051	1.088	0.292	0.941
1993	4.637	7.868	6.511	4.301	6.452	5.292	1.028	0.990	0.908	1.166	1.306	1.709
1994	1.692	6.264	11.375	7.879	16.378	6.225	6.696	7.297	4.662	5.206	1.224	0.377
1995	2.702	6.036	11.133	6.255	13.839	6.430	5.848	14.945	8.313	12.834	5.350	0.336
1996	2.891	9.022	9.449	7.745	10.287	7.736	5.651	7.590	8.834	10.340	11.219	1.468
1997	1.212	8.445	10.830	12.309	13.970	6.769	13.759	11.877	17.852	7.654	3.164	0.369
1998	2.384	8.419	14.266	6.244	8.491	13.170	13.223	18.716	11.303	14.341	4.447	0.814
1999	2.220	0.225	5.196	5.432	12.910	8.390	13.705	14.801	14.946	6.235	22.781	10.454
2000	0.000	2.458	7.796	10.812	12.949	16.912	11.126	12.413	10.336	19.398	15.934	1.796
2001	2.280	10.687	17.207	13.329	12.713	11.208	5.872	8.497	4.327	25.530	25.739	28.928
2002	0.106	12.317	14.810	26.716	12.163	8.193	8.168	13.312	22.815	25.341	47.652	29.528
2003	3.895	25.308	29.125	21.233	14.750	12.139	6.205	1.838	3.677	22.969	59.235	18.043
2004	8.484	40.646	31.707	17.499	30.774	18.458	15.263	3.619	25.090	18.682	60.672	19.235
2005	0.211	19.855	29.290	18.272	1.009	0.158	1.118	0.130	0.067	4.268	10.148	1.410
2006	1.123	0.907	19.201	5.685	0.593	1.061	0.214	0.304	11.908	19.009	15.628	7.344
2007	3.474	7.503	5.919	5.780	7.019	1.667	3.602	4.877	6.615	3.899	2.850	1.175
2008	0.000	0.767	8.000	7.459	1.455	3.664	1.179	1.195	0.000	7.055	9.012	2.913
2009	0.049	9.052	17.895	12.210	7.563	5.036	3.192	1.911	0.063	0.243	0.161	0.003
2010	0.805	7.418	13.821	9.120	9.261	6.335	6.774	3.008	2.184	0.046	8.920	0.644
2011	0.628	7.576	15.555	7.605	5.845	3.998	11.940	6.640	6.664	2.890	0.032	0.026

Table 3b. The monthly sardine commercial catch tonnage (in thousands of tons) landed as directed catch or bycatch with the redeye fishery, east of Cape Agulhas. There was no catch east of Cape Agulhas prior to 1989.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1989	0.000	0.000	0.167	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.047	0.000
1990	0.011	0.031	0.153	0.061	0.046	0.031	0.059	0.014	0.000	0.000	0.057	0.016
1991	0.010	0.224	0.114	0.158	0.272	0.074	0.000	0.000	0.000	0.230	0.134	0.164
1992	0.039	0.039	0.155	0.544	0.387	0.338	0.201	0.013	0.056	0.126	0.352	0.205
1993	0.097	0.234	0.378	0.318	0.227	0.196	0.005	0.152	0.161	0.119	0.142	0.270
1994	0.011	0.633	0.270	0.315	0.561	0.607	0.534	0.481	0.144	0.395	0.072	0.345
1995	0.365	0.743	0.605	0.062	0.481	0.159	0.309	0.135	0.257	0.837	0.594	0.395
1996	0.064	0.533	0.456	0.400	1.073	0.731	0.625	0.539	0.672	0.398	1.136	0.915
1997	0.093	0.290	0.741	0.362	0.640	0.369	1.234	0.134	0.105	0.298	0.000	0.000
1998	0.012	0.000	0.536	0.612	0.972	1.156	0.554	0.069	0.168	0.016	0.100	0.000
1999	0.708	0.061	0.413	0.692	0.817	0.943	0.255	0.408	0.457	0.709	1.006	0.623
2000	0.000	0.271	0.541	0.754	1.444	1.133	0.138	0.688	0.357	0.172	0.505	0.044
2001	0.135	0.304	0.537	0.497	0.657	0.992	1.253	1.798	2.178	1.481	1.152	0.296

Table 3b (continued).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Sep	Aug	Oct	Nov	Dec
2002	0.000	0.885	0.671	0.678	2.493	2.880	4.275	4.873	3.314	3.051	2.712	1.419
2003	0.586	2.005	2.172	2.669	6.255	7.391	9.603	6.849	9.180	6.531	6.066	1.693
2004	0.534	1.660	2.543	4.306	7.630	10.285	10.250	15.521	9.307	9.738	4.287	1.393
2005	0.468	4.889	5.332	10.422	19.516	24.672	25.615	18.544	18.181	9.052	16.047	2.232
2006	0.947	6.454	10.630	12.736	28.192	25.894	17.695	8.775	3.450	3.823	3.469	3.114
2007	0.441	6.538	10.762	12.977	16.470	15.113	7.227	4.603	3.252	0.160	2.033	1.608
2008	0.344	2.088	3.175	13.837	8.529	3.685	7.192	2.254	0.236	1.055	1.055	0.567
2009	0.671	2.725	4.318	6.829	7.009	4.400	3.328	0.374	0.932	1.267	0.876	1.412
2010	0.814	2.443	3.156	2.836	3.460	3.256	3.030	3.262	2.607	0.292	0.032	0.905
2011	0.419	3.086	3.531	1.943	4.615	3.404	3.451	4.578	2.347	0.777	1.326	0.366

Table 3c. The monthly sardine commercial catch tonnage (in thousands of tons) landed as bycatch with the anchovy fishery, west of Cape Agulhas. These data include the small amounts of sardine landed east of Cape Agulhas as described in the text. Note that the sardine bycatch with anchovy RLFs have been recorded according to the sample allocation rule (>50% anchovy by mass in the landing).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987	0.018	0.187	0.280	1.415	0.329	1.462	1.521	1.407	0.206	0.000	0.000	0.000
1988	0.032	0.291	0.115	0.058	1.216	2.391	0.520	0.724	0.154	0.689	0.235	0.000
1989	0.135	2.144	0.970	1.783	2.988	1.576	0.399	0.000	0.000	0.000	0.000	0.000
1990	0.019	0.193	0.477	1.012	2.073	3.797	0.012	0.000	0.000	0.000	0.000	0.000
1991	0.010	0.074	1.473	2.778	0.518	2.174	0.029	0.005	0.000	0.000	0.000	0.000
1992	0.142	0.501	0.465	2.454	1.671	2.565	2.281	2.767	0.277	0.008	0.000	0.000
1993	0.070	0.179	0.500	1.397	1.376	0.204	0.619	1.552	0.559	0.163	0.000	0.000
1994	0.286	1.972	1.683	1.359	4.447	1.936	0.039	3.460	0.032	0.000	0.000	0.000
1995	0.046	0.026	1.024	0.735	1.890	4.306	5.076	6.133	0.447	1.970	0.535	0.000
1996	1.015	1.931	0.689	0.624	1.846	1.960	0.007	0.000	0.000	0.004	0.000	0.000
1997	0.073	0.006	0.005	0.002	0.243	0.267	1.469	0.735	3.226	0.863	0.000	0.000
1998	0.028	1.118	0.143	1.762	3.674	4.492	0.960	0.183	0.697	0.262	0.000	0.000
1999	0.000	0.000	0.318	0.381	1.364	2.288	0.490	0.730	1.393	0.482	0.089	0.000
2000	0.000	0.000	1.403	1.798	1.897	1.146	0.611	0.317	0.030	0.021	0.000	0.000
2001	0.001	0.244	0.243	0.981	2.258	2.623	1.098	3.431	1.291	1.689	0.046	0.028
2002	0.040	0.185	0.000	0.353	0.402	1.836	1.297	5.681	2.709	0.000	0.000	0.009
2003	0.000	0.000	0.182	1.845	2.137	4.290	1.130	0.118	0.280	0.462	0.130	0.000
2004	0.000	0.017	0.002	0.956	3.298	0.474	0.706	0.604	0.186	0.000	0.003	0.000
2005	0.000	0.072	0.995	1.279	1.507	0.384	0.393	0.260	0.520	0.266	0.131	0.000
2006	0.000	0.000	0.142	0.352	0.698	2.303	2.764	0.980	1.818	0.065	0.006	0.000
2007	0.000	0.003	0.061	0.724	1.972	0.365	0.202	0.291	0.123	0.191	0.000	0.004
2008	0.000	0.042	0.156	0.503	1.461	0.756	0.289	0.490	0.137	0.090	0.273	0.004
2009	0.000	0.066	0.181	0.776	0.382	0.327	0.360	0.564	0.059	0.081	0.010	0.000
2010	0.088	0.187	1.856	2.124	2.512	5.356	4.166	1.598	0.036	0.038	0.015	0.000
2011	0.008	0.066	0.162	1.523	3.369	1.257	3.753	1.213	0.000	0.000	0.000	0.000

Table 4. Sardine and anchovy 1+ biomass (in tons) as far as Port Alfred and associated CV from the November acoustic survey and anchovy spawner (1+) biomass and associated CV determined by the DEPM.

	Acoustic								DEPM	
Area	Hondeklip Bay to Port Alfred				Hondeklip Bay to Cape Agulhas		Cape Agulhas to Port Alfred		Full Area	
Year	Anchovy 1+ Biomass (t)	CV	Sardine 1+ Biomass (t)	CV	Sardine 1+ Biomass (t)	CV	Sardine 1+ Biomass (t)	CV	Anchovy 1+ Biomass (t)	CV
1984	1553813	0.282	48378	1.118	48009	1.127	369	0.644	1100000	0.45
1985	1366294	0.211	45013	0.509	25457	0.680	19556	0.767	616000	0.4
1986	2568625	0.172	299797	0.848	238230	1.054	61566	0.672	2001000	0.35
1987	2108771	0.157	111285	0.630	94165	0.734	17120	0.693	1606000	0.3
1988	1607060	0.222	134362	0.957	128043	1.005	6319	0.525	1679000	0.35
1989	751529	0.167	256655	0.274	198328	0.334	58327	0.397	421000	0.35
1990	651711	0.183	289876	0.352	248855	0.382	41020	0.905	723000	0.58
1991	2327834	0.159	597858	0.395	517180	0.444	80678	0.675	2913000	0.35
1992	2088025	0.161	494157	0.658	247756	0.560	246401	1.191	3600000	0.31
1993	916359	0.209	560019	0.427	480822	0.488	79198	0.603	770000	0.34
1994	617276	0.159	518354	0.370	389730	0.432	128624	0.709		
1995	601271	0.217	843944	0.713	363542	0.302	480402	1.229		
1996	162048	0.410	529456	0.471	257763	0.352	271693	0.849		
1997	1482633	0.267	1224632	0.329	964835	0.322	259797	0.982		
1998	1229132	0.217	1607328	0.251	1082547	0.341	524781	0.305		
1999	2052156	0.156	1635410	0.212	708029	0.324	927381	0.280		
2000	4653779	0.125	2292380	0.500	726230	0.633	1566150	0.670		
2001	6720287	0.107	2309600	0.142	669617	0.313	1639983	0.154		
2002	3867649	0.154	4206250	0.227	1184713	0.247	3021538	0.300		
2003	3563232	0.236	3564171	0.197	1343118	0.300	2221053	0.258		
2004	2044615	0.131	2615715	0.334	292522	0.437	2323193	0.372		
2005	3077001	0.144	1048991	0.300	75604	0.524	973386	0.321		
2006	2106273	0.136	712557	0.346	177890	0.414	534667	0.441		
2007	2506984	0.157	252201	0.351	53139	0.541	199062	0.421		
2008	3598790	0.120	384080	0.422	211871	0.528	172209	0.682		
2009	3792547	0.136	501575	0.271	262175	0.285	239400	0.474		
2010	2077414	0.144	508392	0.235	309465	0.328	198927	0.314		
2011	754124	0.204	1037060	0.2353	182825	0.187	854235	0.283		

Table 5. Posterior median anchovy proportion-at-age 1 (by number), with SE in brackets and weights-at-age (in grams) in the November survey, given a model which assumes time-invariant and one which assumes annually varying variance about mean length at age 1 (de Moor and Butterworth, 2012).

	Proportion-at-Age 1		Weight-at-Age			
			Time-invariant variance		Annual variance	
Year	Time-invariant variance	Annual variance	Age 1	Age 2+	Age 1	Age 2+
1984	0.249 (0.16)	0.251 (0.26)	15.637	15.394	15.497	15.408
1985	0.931 (0.12)	0.818 (0.16)	14.285	18.395	13.564	18.998
1986	0.936 (0.08)	0.616 (0.14)	12.093	18.038	10.118	16.168
1987	0.945 (0.08)	0.700 (0.19)	11.981	17.116	10.468	16.714
1988	0.638 (0.21)	0.525 (0.23)	12.396	12.408	11.985	12.675
1989	0.050 (0.04)	0.055 (0.05)	9.842	15.081	11.623	15.02
1990	0.890 (0.09)	0.898 (0.14)	10.146	17.319	10.27	16.928
1991	0.912 (0.12)	0.777 (0.23)	9.918	13.481	9.375	13.576
1992	0.422 (0.19)	0.474 (0.18)	8.85	12.806	9.909	12.412
1993	0.743 (0.20)	0.693 (0.27)	11.686	13.12	11.526	13.275
1994	0.490 (0.20)	0.371 (0.24)	13.044	15.664	12.31	15.569
1995	0.872 (0.07)	0.639 (0.09)	8.101	14.943	6.807	12.775
1996	0.343 (0.05)	0.299 (0.04)	8.708	17.258	7.834	17.083
1997	0.683 (0.14)	0.791 (0.15)	12.362	18.739	13.998	16.743
1998	0.496 (0.07)	0.677 (0.13)	9.656	19.509	12.182	19.905
1999	0.820 (0.08)	0.884 (0.12)	11.301	20.513	12.029	19.728
2000	0.934 (0.09)	0.848 (0.17)	9.688	15.187	9.371	13.833
2001	0.919 (0.06)	0.793 (0.11)	7.728	14.972	7.016	13.034
2002	0.743 (0.16)	0.773 (0.18)	8.86	12.617	9.355	11.921
2003	0.944 (0.08)	0.927 (0.11)	10.112	15.089	9.987	15.483
2004	0.961 (0.24)	0.923 (0.13)	12.346	21.556	12.326	17.117
2005	0.447 (0.10)	0.368 (0.20)	11.005	17.93	9.923	17.42
2006	0.435 (0.08)	0.583 (0.17)	10.667	18.566	12.703	18.499
2007	0.642 (0.05)	0.705 (0.10)	7.927	18.112	8.67	18.462
2008	0.833 (0.04)	0.804 (0.06)	7.282	16.917	7.054	16.234
2009	0.903 (0.08)	0.823 (0.14)	10.617	17.222	10.053	16.566
2010	0.810 (0.21)	0.771 (0.14)	11.022	13.7	11.468	12.353
2011	0.657 (0.10)	0.744 (0.15)	11.044	18.169	11.88	18.114

Table 6. Sardine average weight (in grams) in the November survey for the full area (one stock) and separately for the areas west and east of Cape Agulhas.

Year	Full Area	West of Cape Agulhas	East of Cape Agulhas
1984	43.096	42.932	85.599
1985	44.570	37.299	59.729
1986	39.907	36.104	67.367
1987	43.099	39.862	77.885
1988	46.696	46.589	48.968
1989	71.324	74.147	63.148
1990	78.643	82.997	59.659
1991	54.519	54.409	55.235
1992	49.666	43.646	57.663
1993	50.425	51.257	45.899
1994	76.495	73.081	89.104
1995	65.213	51.384	81.891
1996	61.467	66.067	57.658
1997	68.977	67.664	74.335
1998	54.145	70.252	36.760
1999	64.432	64.025	64.746
2000	59.549	50.687	64.803
2001	43.945	33.857	50.031
2002	59.433	49.832	64.290
2003	56.204	48.805	61.876
2004	67.422	57.147	68.984
2005	61.959	44.307	63.937
2006	38.149	37.986	38.203
2007	33.436	35.735	32.872
2008	31.528	35.814	27.481
2009	51.040	46.572	57.032
2010	38.714	41.006	35.616
2011	72.766	72.824	72.754

Table 7. Sardine and anchovy recruitment (in thousand tons and in billions) from Hondeklip Bay to Cape Infanta and associated CV from the recruitment acoustic survey. The mean recruit weight is also given (in grams). The sardine recruitment and associated CV from Cape Infanta to Cape St Francis is also given for some years.

	Anchovy					Sardine									
						West of Cape Infanta					Cape Infanta to Cape St Francis				
Year	**Biomass (Method 1 of App B)**	**Biomass (Method 2 of App B)**	**CV***	**Mean Weight**	**Numbers***	**Biomass (Method 1 of App B)**	**Biomass (Method 2 of App B)**	**CV***	**Mean Weight**	**Numbers***	**Biomass (Method 1 of App B)**	**Biomass (Method 2 of App B)#**	**CV***	**Mean Weight**	**Numbers***
1985	348.547	344.245	0.276	4.176	83.454	37.424	37.636	0.649	10.420	3.592					
1986	617.558	617.425	0.184	4.433	139.311	45.164	43.240	0.609	12.284	3.677					
1987	676.738	687.636	0.167	5.438	124.450	90.182	89.502	0.554	12.266	7.352					
1988	561.451	561.357	0.164	4.352	129.023	4.444	4.724	0.462	10.134	0.439					
1989	161.470	162.132	0.205	4.874	33.128	47.214	46.239	0.426	22.176	2.129					
1990	169.555	169.587	0.225	3.316	51.140	27.214	28.177	1.079	10.920	2.492					
1991	519.845	521.418	0.151	4.577	113.584	22.864	22.769	0.269	11.939	1.915					
1992	427.933	438.584	0.161	4.568	93.681	68.554	69.608	0.363	12.170	5.633					
1993	448.144	445.794	0.266	3.895	115.058	108.133	109.591	0.367	7.096	15.238					
1994	129.890	135.023	0.184	4.251	30.554	58.091	57.208	0.324	21.886	2.654	19.496	18.227	0.555	28.028	0.696
1995	391.859	391.749	0.179	3.548	110.439	195.250	194.506	0.378	7.691	25.388	4.528	3.388	0.467	19.141	0.237
1996	72.199	72.077	0.220	2.802	25.771	52.678	48.154	0.453	16.441	3.204	7.811	7.547	0.480	19.113	0.409
1997	402.596	402.624	0.186	4.463	90.210	340.160	342.363	0.402	9.229	36.856					
1998	451.514	451.211	0.150	3.307	136.518	124.952	129.664	0.360	11.660	10.716	5.238	5.207	0.540	19.642	0.267
1999	813.098	812.242	0.158	4.081	199.228	220.589	219.249	0.376	21.255	10.378	58.613	53.909	0.519	45.419	1.290
2000	2477.589	2474.927	0.168	3.966	624.675	265.489	264.452	0.390	13.273	20.002	168.591	165.955	0.495	31.870	5.290
2001	2027.740	1946.112	0.135	3.233	627.200	553.538	559.079	0.287	9.216	60.065	0.000	0.003	0.713	9.932	0.000
2002	1541.803	1543.397	0.115	2.963	520.413	610.344	595.913	0.182	12.417	49.153	41.495	37.613	0.958	31.103	1.334
2003	1391.468	1396.638	0.189	3.234	430.308	508.911	501.624	0.209	13.963	36.448	19.948	19.553	0.553	43.572	0.458
2004	1060.548	1058.653	0.219	4.445	238.569	25.871	26.003	0.342	6.326	4.089	4.187	4.477	0.732	7.191	0.582

* Data to which the assessments are tuned.

Blank cells correspond to years for which the survey did not reach Cape St. Francis.

Table 7 (continued)

	Anchovy					Sardine									
						West of Cape Infanta					Cape Infanta to Cape St Francis				
Year	**Biomass (Method 1 of App B)**	**Biomass (Method 2 of App B)**	**CV***	**Mean Weight**	**Numbers***	**Biomass (Method 1 of App B)**	**Biomass (Method 2 of App B)**	**CV***	**Mean Weight**	**Numbers***	**Biomass (Method 1 of App B)**	**Biomass (Method 2 of App B)#**	**CV***	**Mean Weight**	**Numbers***
2005	535.958	550.235	0.273	3.029	176.917	16.736	16.896	0.343	5.823	2.874	20.658	21.754	0.460	19.357	1.067
2006	259.194	263.889	0.174	2.207	117.465	49.926	50.067	0.381	5.220	9.564	62.564	62.881	0.649	17.721	3.530
2007	1499.082	1505.898	0.184	2.959	506.703	29.689	32.777	0.343	10.110	2.937	17.985	19.215	0.892	13.506	1.332
2008	1432.841	1426.705	0.202	2.544	563.156	20.555	19.610	0.266	5.337	3.852					
2009	1307.613	1306.045	0.189	3.598	363.387	57.740	55.111	0.776	6.271	9.207	64.360	63.474	1.018	17.762	3.623
2010	1667.695	1667.994	0.267	4.351	383.328	477.437	479.609	0.473	13.423	35.569	6.984	6.781	0.924	20.076	0.348
2011	281.249[4]	281.260	0.283	2.700	104.166	53.624	53.681	0.475	9.80	5.470					

* Data to which the assessments are tuned.

Blank cells correspond to years for which the survey did not reach Cape St. Francis.

4 Biomass up to Cape Infanta was estimated by taking that observed up to Cape Agulhas, increased by 0.03 (de Moor and Butterworth 2011)

Appendix A: Pelagic sample allocation

The sample allocation method is the process whereby a length frequency is allocated to every commercial landing, enabling the transformation of the catch to its raised length frequency (RLF). The commercial catch data and field station length frequency data are entered and stored on a Sybase database on the MCM network and the calculations are performed in Access.

Species

For the assessments which serve as the operating models to test Operational Management Procedures it is necessary to calculate RLFs for anchovy (*Engraulis encrasicolus)* and sardine (*Sardinops sagax)* though RLFs for round herring (*Etrumeus whiteheadii)* and horse mackerel (*Trachurus trachurus capensis)* are also generated for every run.

Data sources

- Commercial catch: The skipper completes a skipper form for every trip and records the estimated catch and the geographic position of individual throws. The scale monitor contract was awarded to Nosipho Consultants in 2002. They sample every landing for its species composition and tonnage landed. Prior to 2002 this was the task of the fisheries inspector and hence the catch sheet is referred to as the inspector's form. Skipper data are available on Sybase from 1984 onwards but inspector data were obtained only from 1987. MCM field station personnel collect data sheets and enter the information on Sybase.
- Field station samples: MCM field station personnel collect random samples at the major pelagic fishing harbors for species composition and length frequency (Capricorn fishing was contracted from 2002 until 2005 to man St. Helena Bay and Gansbaai). Samples of industrial fish such as anchovy and round herring are obtained from the top of the hold before the vessel discharges. For this reason industrial samples are obtained mainly from the last throw of the trip. Offloading further damages the already partially-decomposed fish and one cannot sample from the conveyer belt because it would be impossible to weigh those fish. Directed sardine catch, on the other hand, is kept in a very good condition onboard on ice and good quality samples are easily obtained from the conveyor belt, whilst the vessel is discharging. Unfortunately it is seldom possible to establish which throw is being sampled. Field station data are available on Sybase from 1984 onwards. Ports sampled over the period include Lamberts Bay, Laaiplek, St. Helena Bay, Saldanha, Cape Town, Hout Bay, Kalk Bay, Hermanus, Gansbaai, Mossel Bay and Port Elizabeth.
- Observer samples: The observer program started in 1999 but onboard biological sampling was started only in 2001. Observer sampling results reflect an improvement on the field station data

because samples are obtained from a known throw, all throws are sampled and the fish is always in a good condition. Unfortunately the length frequency samples have to be taken ashore for weighing and this gives rise to room for error. The data are stored in an Access database called CAPFISH.

Data extraction from Sybase

- Catch data are extracted from Sybase as text (flat) files; *throw.csv* contains the skippers' data and *catch.csv* contains the inspectors' data.
- Field station data are extracted in the same manner; *spcomp*.csv contains the species composition data and *lfreq.csv* contains the length frequency data.

Data handling and evaluation

<u>MCM data</u>

- Unfortunately there is no manual proof reading of all the data, except in cases where the number of throws is excessive (more than 10) and the trip duration is of an unrealistic duration (more than 3 days). Data evaluation is limited to electronic checking for noticeable mistakes.
- A duplicate dataset of *catch.csv* which is regularly updated by email is kept at Saldanha in an Access table. This means that the data are entered twice, but into separate databases and this allows for the comparison of the two data sets on a regular basis for differences and errors. It might appear unnecessary to keep two data sets, but this is the sole reason that the pelagic catch data remain representative of what was recorded by the scale monitors.
- The expected sample weights associated with the length frequency data in *lfreq.csv* are computed and samples that deviate more than 30% are flagged and checked against the raw data. If a flag results from a punch error then the data are corrected, but in the case of a sampling error the record is deleted from the data base.
- Suspect positions, for example areas outside the normal catch areas are checked against the raw data and, if necessary, corrected.

<u>Observer data</u>

- Limited manual proof reading of data
- Only observer trips that match the commercial data for vessel name and date are used. Mismatched dates do occur, making it very difficult to establish whether a specific vessel carried an observer on a specific date. Therefore samples from such observer trips are ignored to prevent the inclusion of poor data. Only trips that do link can be used, because the scale monitor's species composition is used to determine the target species of the length frequency sample.

- The structure of the observer length frequency table is altered to make it compatible with the Sybase dataset.
- Only observer length frequencies whose predicted sample weights fall within the set range are used. Data with possible measurement errors or wrong species names are excluded.

Access programs

1) Capfish.mdb (observer data)
2) RLFdata.mdb (where the RLFs are generated)

General program outline

- Catches are allocated to pool-area/week strata:
    1. Week: the throw date with the largest catch is used.
    2. Pool area: the existing 21 areas (see Figure A.2) are used, but in 1999 area 21 was subdivided into areas 23 and 24, to accommodate the eastward fishing expansion. The throws within each landing are examined, and the throw with the greatest mass is used as the representative throw.
    3. Assign a target species to every catch. The species with the largest mass is defined as the dominant species in the landing.
- The length frequency samples are grouped by species and target species for the pool-area/week strata and summed.
- A new catch table with additional space for the allocated length frequencies is created.
- The length frequency table is searched and a frequency based on the species, target species, week and pool area criteria are assigned to the catch table.
- In the event of catches not being represented by an appropriate sample, the pool-area/week will be expanded to include surrounding areas and weeks. Stratum expansion continues alternately by week and pool until an appropriate frequency is located.
- If no appropriate sample is found then the average sample for the month is applied. Where no sample for the month exits in the case of anchovy, the raised length frequency is estimated using the raised length frequency of a former month as detailed in the text. Where no sample for the month exists in the case of sardine, the previous month is used. Catches of each species and the length frequencies are summed by month over larger user specified areas.
- The RLFs are exported as Excel files in numbers per length group.

The user specified areas that are used are:

1. Areas 1-6: North of Cape Columbine
2. Areas 7-12: Cape Columbine to Cape Point

3. Areas 13-20: Cape Point to Cape Infanta
4. Area 23: Cape Infanta to Plettenberg Bay
5. Area 24: East of Plettenberg Bay

In 2007 three new areas were introduced because of planned changes to the OMP:

1. West: West of 20 degrees east (West of Cape Agulhas)
2. South: East of 20 degrees east and west of 24 degrees 50 minutes east (between Cape Agulhas and Cape St. Francis)
3. East: East of 24 degrees 50 minutes east (East of Cape St. Francis)

Although the RLFs are summarized according to different areas, the allocation process is still based on the original pool areas, with the exception of those cases where pool areas were split by the new borders.

Program changes

In January 2007 four changes were made to the process above:

- The observer length frequencies were included.
- To prevent juvenile sardine frequencies from being allocated to adult sardine catches, the species was separated into directed and by catch for allocation purposes. This is applicable only when sardine is landed as a by catch with anchovy. Sardine by catch with anchovy is mainly juvenile fish whereas by catch with round herring it is mostly adult fish.
- Noticeable error in the RLF results when the field station catch composition data are used to identify the target species of the length frequency sample, and these composition data differ from those of the scale monitor. Because the field station data are not proofread, and given the inclusion of the observer length frequencies (they also need a target species to be identified), it was decided to standardize on the scale monitors species composition as the only source.
- Missing skipper data (catch area) are catered for. This occurs when the skipper fails to hand in a trip sheet. Currently this is not a major problem but it did happen in the 1980s and 1990s. Where the *catch.csv* file does not have a related record in the *throw.csv* file, the program will search for the most likely catch position, based on the catch type of the other vessels for the same date.

The first change leads to enhanced coverage, especially in the case of industrial fish, i.e. anchovy that are poorly sampled by the field stations. The last three changes were implemented to prevent errors caused by bad data or poor sampling coverage. This can typically be seen in a RLF plot as an improbable peak at a certain length group.

In March 2007 an additional change was implemented. Towards the end of the year sporadic landings can be overlooked, because it is not cost effective to continue extensive sampling. These landings are generally small but it is still necessary to allocate a size to the fish. In the past the annual RLF average was used, but it was felt that it is better to allocate the length frequency from the adjacent month. The length frequencies are first stratified by area and species type, but where no match is found the requirements for matching area and target species are removed alternatively until a match is found.

Even though throws in multiple pool areas during a single trip do occur, only the catch area for the biggest throw is selected. This is done in order to keep continuity with the old sample allocation method. A change that could be considered would be to allocate a sample to every throw as opposed to every trip. The scale monitor samples at regular intervals and discrete throws are not sampled. However, if one assumes the species composition of the throws are uniform, then the catch per throw can be calculated, by proportionally applying the species composition to individual throws. Observer sampling is ideally suited for this approach, because every throw is sampled, but greater sampling coverage and matched skipper throws are required.

Sampling coverage required

Optimum sample size and sampling coverage can be determined only by using a suitable statistical study, and one can therefore only speculate on the sample size required. Logistic constraints have necessitated a random stratified sampling method, and the grouping of catches and samples on a week/pool-area basis has been adopted since electronic data processing began. Both the sampling and the raised length frequency approaches are arguably the most suitable considering the fishing strategy and the available data. The percentage coverage per stratum is readily quantified, and the first level pool-area/week coverage could possibly be used as an index of sampling coverage. 100 percent coverage is not attainable because of financial and logistic constraints, and it is more than likely unnecessary. From Figure A.1 it appears that 80 percent coverage is attainable when the field station and observer samples are combined.

Many factors influence the relationship between the number of samples taken and the coverage obtained, but in general more samples will lead to better coverage. This partially explains the declining trend of the field station data in Figure A.1. Directed sardine samples are easily obtained but industrial fish have to be collected from the hold of the vessel, a difficult and unpleasant task. The numbers of buckets to be taken at the field stations are prescribed, but when a decision has to be taken on the fish type by the field station worker, then the ice fish is favoured more often than not. Directed sardine from all areas (except Port Elizabeth) are processed at the canneries in the St. Helena Bay area and because the field station is manned regularly, good coverage was attained. Erratic sampling at Saldanha Bay, Hout Bay and Gansbaai also contributed to the decrease of industrial fish coverage. With the inclusion of observer samples however, the target percentage is reached for anchovy and juvenile sardine by catch. If 80 percent is a realistic benchmark, then one can then conclude that the sampling effort (regarding TAC species) for the time period 2001 to 2006 was adequate. It has to be stressed that this was achieved only with the inclusion of samples from the observer program.

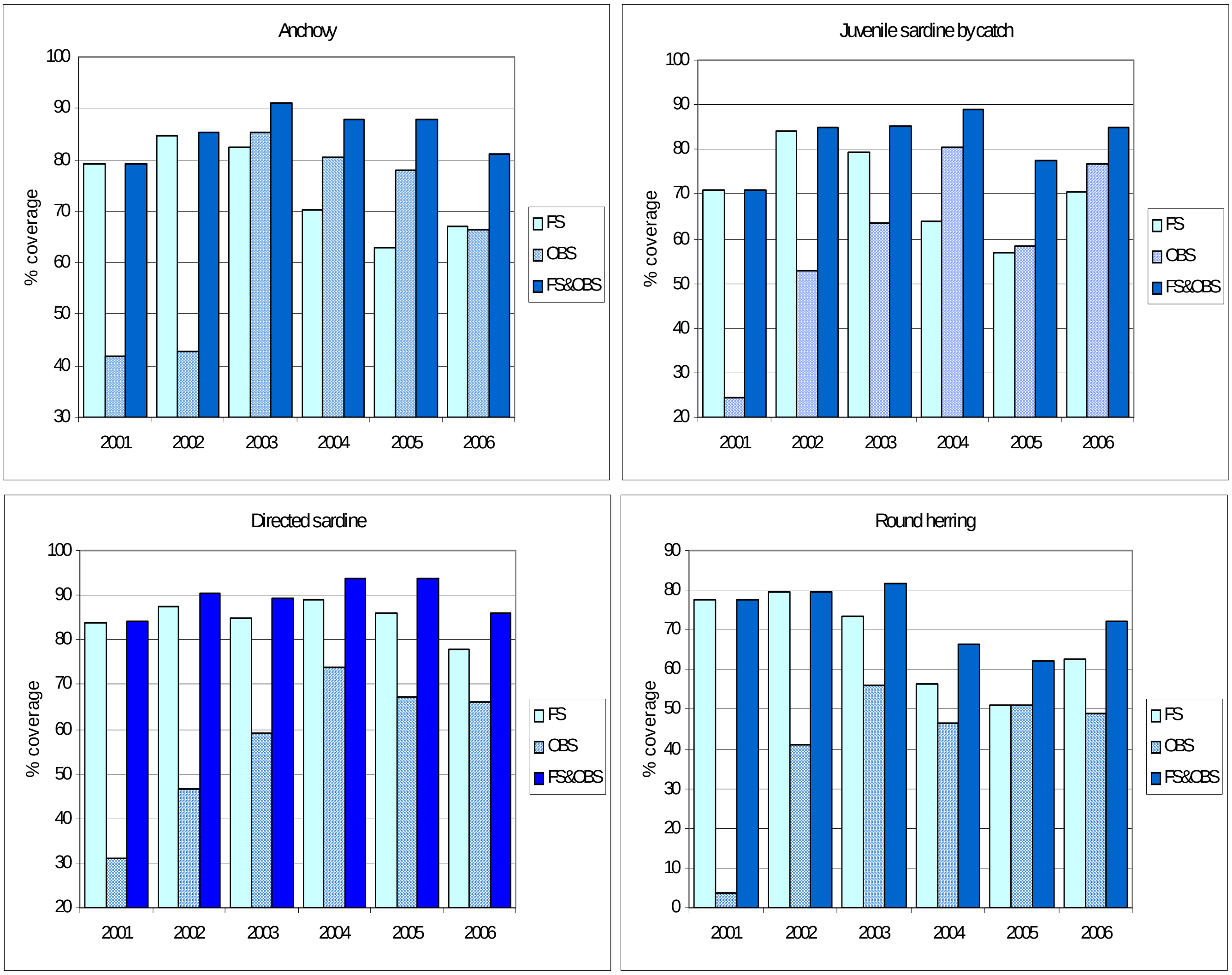

Figure A.1. Coverage obtained on a first level pool-area/week for the field stations (FS), the observers (OBS) and a combination of the two (FS&OBS).

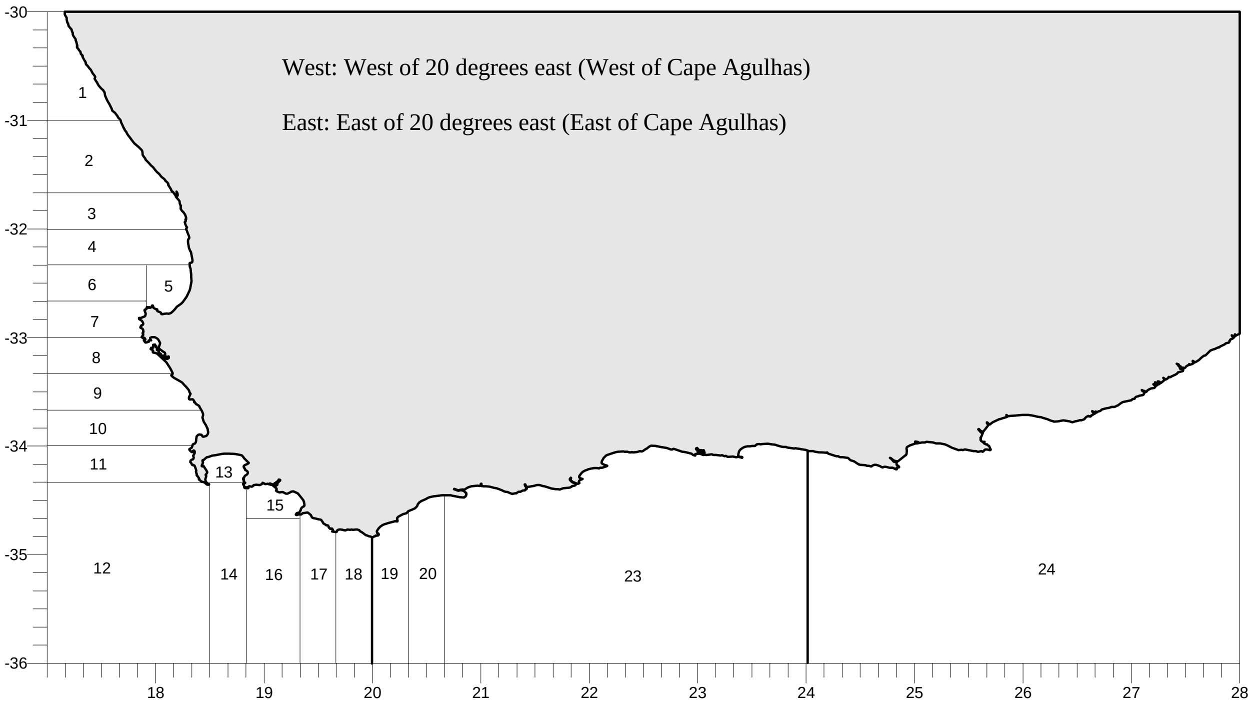

Figure A.2. The pool areas that are used for sample allocation and the two larger areas that are used for the OMP revision.

Appendix B: Methods Used to Calculate Recruit Biomass

Two different methods are used to calculate recruit biomass. The first has been used since the start of the time series and is used to calculate recruit numbers, while the second was devised as a method to estimate CVs of recruit-only biomass. The biomasses differ between the methods due to the differences in the way the densities are weighted.

Method 1

This method, designed by Ian Hampton and Beatriz Roel, has been used since the start of the time series and calculates recruit biomass, number of recruits (less than a certain cut-off length) and a recruit mean weight:

1) The acoustic biomass per stratum (of adults and recruits) is calculated using the Jolly and Hampton method (i.e., each interval is weighted by interval length and a mean density per transect is calculated. Each transect is again weighted by its length to get a mean density per stratum).
2) Each acoustic interval has been linked to a particular grid reference (trawl sample) which was used to scale the acoustic energy to density. The trawl sample has a length frequency (LF) and associated length frequency mass (LFMASS). This LF and LFMASS include both adults and recruits as it is impossible at this stage (at sea) to know what the cut-off length for a recruit is. The LFMASS is the total weight of the LF sample (the combined weight of all fish of a particular species measured for the LF distribution).
3) For each interval, the acoustic density is multiplied by the interval length. This weighted interval density is then summed over all intervals for each grid reference, per stratum and per species to give an acoustic weighting to each grid reference, $W_{GR}(grid,stratum,species)$.
4) The weighted grid reference is then summed over all grid references for each stratum and species to give a weighted grid reference per stratum for each species, $W_{GR}(stratum,species)$.
5) For each length class of each grid reference, calculate a Trawl WF (trawl weighting factor) $=W_{GR}$(grid,stratum,species)/LFMASS. This converts the acoustic weighting (in terms of mass) into a factor in terms of numbers.
6) The length frequency (LF) is then weighted by this Trawl WF and summed for each length class to give a weighting to each length class (Lgroup) for each stratum for each species sum(number*trawl WF), *WLF(Lgroup,stratum,species)*.
7) *WLF(Lgroup,stratum,species)* is then scaled to the biomass of the stratum: $BLF(Lgroup,stratum,species)=[WLF(Lgroup,stratum,species)]*[BIOMASS(stratum,species)]/[\Sigma W_{GR}(stratum,species)]$.
8) BLF is then summed across all strata for each species to give a final length frequency per species for the survey (this is done separately up to Cape Infanta and for the whole survey).
9) For each species an age/length matrix is then generated using a cut-off length for recruits.

10) The proportion in each length class is multiplied by BLF to get the total number of 0-year olds (recruits) and the total number of 1-year olds (adults). This is again done separately as far as Cape Infanta and for the whole survey. The number of fish in each length class is then multiplied by a length weight regression to get an estimated weight (in grams) for each length class, where $w = 0.00924 \times Lgroup^{3.046}$ for anchovy and $w = 0.0096 \times Lgroup^{3.075}$ for sardine.

11) The numbers and weights are then summed across all length classes for each species to give total number of 0-year-olds, $N_{tot,0}$, and 1-year-olds, $N_{tot,1}$, and total weight of 0-year-olds, $W_{tot,0}$, and 1-year-olds, $W_{tot,1}$.

12) The mean weight of 0-year-olds and 1-year-olds is then calculated by $MW_a=(W_{tot,a}/1000000)/N_{tot,a}$. The calculated biomass is then $B_{calc}=MW_0*N_{tot,0}+MW_1*N_{tot,1}$ and should be close to the acoustic biomass, $B_{acoustic}$. B_{calc} and $B_{acoustic}$ are not always identical because in some years the fish are heavier/lighter than that predicted by the length weight regression. The mean weight of recruits and 1–year-olds is weighted by the ratio of the calculated to actual acoustic biomass to get a corrected mean weight: $CMW_a=MW_a*B_{acoustic}/B_{calc}$.

Method 2

This method was devised to map recruit only density rather than the density of combined adults and recruits. In summary the density in each interval is multiplied by the proportion of recruits in that interval to get a recruit only density. The proportion of recruits in each interval is obtained by calculating the proportion of acoustic energy backscattered by recruits only, based on the length frequency that each interval has been assigned and a cut-off length:

1) For each trawl (grid) the acoustic back scattering for each length class is calculated for each species and multiplied by the number of fish in that length class (basically applying the species specific target strength relationship to the length class (L_t)):

$$BS = \begin{cases} 10^{0.1\times -21.12} \times L_t^{-12.15/10} \times N & if\ Sp = 1 \\ 10^{0.1\times -13.21} \times L_t^{-14.9/10} \times N & if\ Sp = 2\ or\ 5 \\ 10^{0.1\times -7.75} \times L_t^{-15.44/10} \times N & if\ Sp = 3\ or\ 4 \end{cases}$$

where *Sp* 1 = anchovy, *Sp* 2 = sardine, *Sp* 3 = horse mackerel, *Sp* 4 = mackerel and *Sp* 5 = round herring.

2) The backscattering (*BS*) is summed for each species for each trawl to give a total backscatter for each grid, BS_{tot}.

3) The backscattering due to recruits, BS_{rec}, is then calculating by summing *BS* for only the length classes less than the cut-off length for each species for each trawl. The cut-off length is obtained from the modal progression analysis after using Method 1 above to weight the length frequency of the entire survey.

4) The proportion of recruits in each trawl is then calculated by BS_{rec}/BS_{tot}.

5) This proportion is then multiplied by the original interval density (of recruits and adults) to obtain the recruit only density (for all years).

6) This recruit only density is used in the regressions of capped to uncapped data in order to estimate (using the Jolly and Hampton weighting procedure) the uncapped recruit only biomass prior to 1997 together with a CV.