A record of the generation of data used in the 2011 sardine and anchovy assessments

de Moor, C.L.[#] , van der Westhuizen, J.J.[+], Durholtz D.[+] and Coetzee, J[+].

Correspondence email: *carryn.demoor@uct.ac.za*

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 2010 and 2011. All files referred to below are available from the first author.

Anchovy Commercial Data

<u>Monthly Raised Length Frequencies (RLFs)</u>

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*.

[#] MARAM (Marine Resource Assessment and Management Group), Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch, 7701, South Africa.

[+] Department of Agriculture, Forestry and Fisheries – Branch Fisheries, Private Bag X2, Rogge Bay, 8012, South Africa.

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
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**

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 2010. 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 kilograms 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: $\frac{\sum_m M_m^{juv} \times N_m^{juv}}{\sum_m N_m^{juv}}$ and $\frac{\sum_m M_m^{ad} \times N_m^{ad}}{\sum_m N_m^{ad}}$, 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: $N_{l,partmonth,a} = N_{l,fullmonth,a} \times SkipperT_{partmonth} / SkipperT_{fullmonth}$, 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. These have been split by area (east and west of Cape Agulhas).

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 Deon Durholtz, these ALKs have not been used in the assessments. Monthly ALKs for sardine commercial catch from 2004, 2006, 2007 and 2008 were derived by Cynthia Mtengwane. Once any differences for reader error have been considered, these ALKs will be used in the sardine assessment.

Proportions-at-length in the commercial catch, computed directly from the RLFs were used may also be used to fit a length based model in due course. These RLFs are available by month between 1984 and 1986 and by area (east and west of Cape Agulhas) and month between 1987 and 2010 and are stored in *Sardine RLFs by area.xls*. 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 the single stock assessment, 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.

<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. The cut-off lengths used to calculate the recruit survey biomass, based on a modal progression analysis (Coetzee and Merkle 2007) are also applied to the calculation of the recruit catch between 1 May and the day before the survey commenced. 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:

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

[1] The LFs assigned to some trawls slightly east of Cape Agulhas would likely have been from Gaansbaai 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.

	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.xls* and given in Table 2.

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*.

Although anchovy ALKs for the November surveys from 1992 to 1995 were derived by Prosch (De Oliveria 2003), these unpublished data are no longer available. A combined 1992-1995 Prosch ALK is, however, available and was used for all years from 1984 to 2010 to estimate the anchovy weight-at-age and proportion of 1-year-olds in the November survey. These data are listed in Table 5 and the combined ALK is stored in *Anchovy92-95AvgALK.xls*. It is odd that in some years the weight-at-age 4 is less than the weight-at-age 3 and also sometimes weight-at-age 3 in year y < weight-at-age 2 in year y-1 and weight-at-age 4 in year y < weight-at-age 3 in year y-1. No explanation for this is available. To test the robustness of the model to the estimates of proportion of 1-year-olds derived using the combined ALK in the November survey, estimates of the proportion (by number) of 1-year-old were also derived assuming a 10cm, 10.5cm and 11cm cut-off length. These data are also listed in Table 5.

Sardine ALKs for the November surveys derived by Deon Durholtz are available by area (east and west of Cape Agulhas) only for 1993, 1994, 1996, 2001 - 2004 and 2006 - 2009. ALKs for the November surveys from 1984-1999 derived by Michael Kerstan are also available (De Oliveria 2003), but inconsistencies between the two sets of ALKs restricted the use of ALKs from both readers. These ALKs were used to calculate the proportion-at-age and weight-at-age in the November survey (Table 6). There were cases where no sardine of a particular length class were aged, while fish of that length class were observed in the survey. Many of these were for the smaller or larger length classes which were then assigned to age 0 or 5+. 'Middle' length classes were assigned to ages similar to those of the length classes directly above and below. Due to the small sample sizes of the 5+ age group in 1996 and 2001, the weight-at-age 5+ was calculated to be smaller than that of age 4. In these two years, therefore, the weight-at-age 5+ was set equal to that of age 4. The weight-at-age for years during which sardine abundance was at a peak (2001-2004) is on average lower than that for the remaining years (1993, 1994, 1996 and 2006-2009). To account for this apparent change in weight-at-age during the period of peak abundance, the average weight from 2001 to 2004 is used in 2000 when the sardine abundance was at a peak and the average weight from 1993, 1994, 1996 and 2006 is used in the remaining years. The ALKs and the method used to calculate the proportion-at-age and weight-at-age are stored in *Nov survey prop at age.xls*, *Nov survey prop at age_west of Cape Agulhas.xls* and *Nov survey prop at age_east of Cape Agulhas.xls*.

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). The time series of biomass and associated CVs is given in Table 8 for sardine and anchovy. The average recruit numbers at the time of the survey were calculated dividing the annual biomass by the average recruit weight. This 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, given the time frame available, the difference between the biomass from the two methods could not be narrowed. 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_FINAL.xls* and *AnchovyMayCalibration_FINAL.xls*.

References

Coetzee, J., and Merkle, D. 2007. Revised estimates of recruit biomass using adjusted recruit length cut-offs. MCM document MCM/2007/FEB/SWG-PEL/01. 2pp.

Coetzee, J.C., Merkle, D., de Moor (formerly Cunningham), C.L., Twatwa, N.M., Barange, M., and Butterworth, D.S. 2008. Refined estimates of South African pelagic fish biomass from hydro-acoustic surveys: quantifying the effects of target strength, signal attenuation and receiver saturation. African Journal of Marine Science 30(2):205-217.

de Moor (formerly Cunningham), C.L., Butterworth, D.S., and Coetzee, J.C. 2008. Revised estimates of abundance of South African sardine and anchovy from acoustic surveys adjusting for echosounder saturation in earlier surveys and attenuation effects for sardine. African Journal of Marine Science 30(2):219-232.

Cunningham, C.L. and Butterworth, D.S. 2007. Proposed Cut-Off Lengths to Split Recruits and Adults for Anchovy Commercial Landings. MCM document MCM/2007/FEB/SWG-PEL/08. 15pp.

De Oliveira, J.A.A. 2003. The Development and Implementation of a Joint Management Procedure for the South African Pilchard and Anchovy Resources. PhD Thesis, University of Cape Town, South Africa.

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

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 numbers) 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	12.285776	4.781	<15.5	0.1641	0.0000
1986	10-Jun	1.300	<10.5	21.077845	4.623	<15.5	0.3399	0.0000
1987	20-Jul	2.613	<11.0	14.324998	7.849	<15.0	0.1859	0.0000
1988	27-Jun[2]	1.867	<11.5	13.416153	4.447	<16.0	0.3184	0.0000
1989	08-Jun[3]	1.233	<10.5	12.459006	5.840	<16.0	0.3680	0.0000
1990	22-Jun	1.700	<10.5	31.037845	4.329	<16.0	0.7266	0.0000
1991	07-May	0.194	<10.5	12.483650	5.220	<16.0	0.0078	0.0000
1992	13-May	0.387	<10.5	12.200420	3.947	<16.0	0.0288	0.0000
1993	21-May	0.645	<10.5	1.471250	5.551	<16.0	0.0473	0.0001
1994	05-May	0.129	<10.5	4.316175	4.700	<16.0	0.0687	0.0000
1995	10-Jun	1.300	<10.5	12.433369	5.665	<16.0	0.5838	0.0000
1996	05-Jun	1.133	<10.5	4.080647	4.528	<15.0	0.3511	0.0000
1997	17-May	0.516	<10.0	0.163541	6.241	<14.0	0.0358	0.0000
1998	20-May	0.613	<10.5	5.995158	6.264	<14.0	0.4242	0.0000
1999	10-May	0.290	<10.0	1.771712	5.056	<17.0	0.0252	0.0001
2000	15-May	0.452	<9.5	7.989902	5.990	<17.0	0.0849	0.0001
2001	05-May	0.129	<9.0	4.908445	5.347	<12.0	0.0003	0.0000
2002	05-May	0.129	<11.0	2.581755	7.000	<16.0	0.0346	0.0000
2003	14-May	0.419	<10.0	3.023380	4.990	<16.0	0.0864	0.0007
2004	08-May	0.226	<11.0	3.923131	5.762	<14.0	0.0360	0.0000
2005	13-May	0.387	<9.5	3.821107	6.550	<13.5	0.1007	0.0000
2006	19-May	0.581	<9.5	0.882745	5.220	<15.0	0.0368	0.0001
2007	18 May	0.548	<9.5	5.824435	5.626	<12.5	0.0507	0.0000
2008	21 May	0.645	<9.5	3.697926	6.664	<10.5	0.1082	0.0000
2009	15 May	0.452	<10.5	7.398002	3.440	<12.5	0.0317	0.0000
2010	27 May	0.8387	<11.0	6.725074	5.057	<13.5	0.2794	0.0017

[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), west of Cape Agulhas.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	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
1985	3.641	5.715	6.198	4.255	3.274	5.640	1.964	0.011	0.014	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
1987	3.693	6.509	7.293	7.053	2.179	2.860	2.045	1.625	0.272	0.000	0.000
1988	1.856	5.603	2.854	5.950	5.120	6.550	3.144	2.047	0.507	0.896	1.147
1989	1.508	4.692	8.433	6.122	5.627	4.554	2.336	0.774	0.178	0.037	0.176
1990	3.036	6.206	8.154	7.581	11.411	8.622	3.600	5.149	1.715	0.695	0.344
1991	2.536	6.202	5.490	8.937	7.969	7.726	5.728	3.999	1.586	1.098	0.124
1992	0.923	5.648	6.059	4.787	3.636	9.620	5.158	8.114	6.328	1.096	0.292
1993	4.707	8.047	7.011	5.739	7.828	5.496	1.647	2.542	1.467	1.329	1.306
1994	1.977	8.236	13.058	9.239	20.825	8.162	6.735	10.757	4.694	5.206	1.224
1995	2.747	6.089	12.158	6.990	15.730	10.736	10.924	21.078	8.760	14.804	5.884
1996	3.906	10.954	10.167	8.369	12.134	9.697	5.657	7.590	8.834	10.344	11.219
1997	1.284	8.451	10.835	12.311	14.213	7.037	15.402	12.612	21.079	8.517	3.164
1998	2.412	9.536	14.409	8.006	12.165	17.662	14.183	18.899	12.001	14.604	4.447
1999	2.220	0.225	5.513	5.814	14.274	10.678	14.195	15.531	16.339	6.717	22.870
2000	0.000	2.458	9.199	12.610	14.846	18.058	11.736	12.731	10.366	19.419	15.934
2001	2.281	10.931	17.451	14.309	14.972	13.831	6.970	11.929	5.618	27.219	25.785
2002	0.146	12.502	14.810	27.069	12.565	10.029	9.465	18.993	25.524	25.341	47.653
2003	3.895	25.308	29.307	23.079	16.886	16.429	7.335	1.956	3.957	23.431	59.365
2004	8.485	40.662	31.709	18.455	34.071	18.932	15.969	5.986	26.365	22.716	60.675
2005	0.211	19.927	30.285	20.879	6.860	0.840	1.886	0.693	0.587	5.007	10.766
2006	1.123	0.907	19.342	6.271	1.304	3.364	2.978	1.284	13.726	19.074	15.634
2007	3.474	7.525	5.981	6.504	9.218	2.029	3.804	5.168	6.738	4.090	2.850
2008	0.000	0.809	8.143	7.962	2.917	4.420	1.468	1.685	0.137	7.146	9.285
2009	0.049	9.119	18.076	12.986	7.946	5.363	3.546	2.474	0.122	0.325	0.171
2010	0.893	7.571	15.677	11.244	11.782	11.691	10.940	4.682	2.219	0.083	0.000

Table 3b. The monthly sardine commercial catch tonnage (in thousands of tons), east of Cape Agulhas. There was no catch east of Cape Agulhas prior to 1989.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	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
1990	0.011	0.031	0.153	0.061	0.046	0.031	0.059	0.014	0.000	0.000	0.057
1991	0.010	0.224	0.114	0.158	0.272	0.074	0.000	0.000	0.000	0.230	0.134
1992	0.000	0.039	0.155	0.544	0.387	0.338	0.201	0.013	0.056	0.126	0.352
1993	0.097	0.234	0.378	0.276	0.227	0.196	0.005	0.152	0.161	0.119	0.142
1994	0.011	0.633	0.270	0.315	0.561	0.607	0.534	0.481	0.144	0.395	0.072
1995	0.365	0.716	0.605	0.062	0.481	0.159	0.309	0.135	0.257	0.837	0.594
1996	0.064	0.533	0.427	0.400	1.073	0.731	0.625	0.539	0.672	0.398	1.136
1997	0.093	0.290	0.741	0.362	0.640	0.369	1.061	0.134	0.105	0.298	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
1999	0.708	0.061	0.413	0.692	0.817	0.943	0.255	0.408	0.457	0.709	1.006
2000	0.000	0.271	0.541	0.754	1.444	1.133	0.138	0.688	0.357	0.172	0.505
2001	0.135	0.304	0.537	0.497	0.657	0.992	1.253	1.798	2.178	1.481	1.152
2002	0.000	0.885	0.671	0.678	2.493	2.880	4.275	4.873	3.314	3.051	2.712
2003	0.586	2.005	2.172	2.669	6.255	7.391	9.603	6.849	9.180	6.531	6.066
2004	0.534	1.660	2.543	4.306	7.630	10.285	10.250	13.757	8.218	5.704	4.287
2005	0.468	4.889	5.332	9.093	15.173	24.374	25.240	18.241	18.181	8.579	15.560
2006	0.947	6.454	10.630	12.502	28.180	25.894	17.695	8.775	3.450	3.823	3.469
2007	0.441	6.518	10.762	12.977	16.243	15.116	7.227	4.603	3.252	0.160	2.033
2008	0.344	2.088	3.189	13.837	8.529	3.685	7.192	2.254	0.236	1.055	1.055
2009	0.671	2.725	4.318	6.829	7.009	4.400	3.334	0.374	0.932	1.267	0.876
2010	0.814	2.443	3.156	2.836	3.461	3.256	3.017	3.250	2.626	0.277	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	712553	0.346	177885	0.414	534667	0.441		
2007	2507501	0.157	256727	0.345	57666	0.503	199061	0.421		
2008	3705893	0.120	384080	0.422	211871	0.528	172209	0.682		
2009	3792547	0.136	502254	0.271	262853	0.285	239400	0.474		
2010	2077414	0.144	508392	0.235	309465	0.328	198927	0.314		

Table 5. Anchovy proportion-at-age 1 (by number) and weight-at-age (in grams) in the November survey.

	Proportion-at-Age 1				Weight-at-Age			
Year	**Combined ALK**	**10cm cut-off**	**10.5cm cut-off**	**11cm cut-off**	**Age 1**	**Age 2**	**Age 3**	**Age 4**
1984	0.422	0.051	0.124	0.369	12.794	15.149	16.618	17.205
1985	0.474	0.103	0.256	0.484	11.422	14.773	17.022	17.561
1986	0.670	0.390	0.587	0.713	10.016	14.129	16.267	17.334
1987	0.719	0.450	0.646	0.775	9.984	14.049	16.422	17.770
1988	0.637	0.219	0.522	0.738	10.253	13.088	15.342	16.822
1989	0.354	0.043	0.061	0.187	12.348	14.375	15.403	15.617
1990	0.747	0.498	0.663	0.817	8.788	13.524	16.179	17.703
1991	0.730	0.443	0.636	0.791	8.373	12.069	14.041	15.285
1992	0.624	0.297	0.445	0.646	8.924	12.616	13.995	14.977
1993	0.546	0.189	0.334	0.553	9.620	12.647	14.180	14.898
1994	0.402	0.116	0.223	0.327	11.090	14.616	15.896	16.067
1995	0.740	0.574	0.678	0.761	7.011	11.268	13.563	14.162
1996	0.488	0.333	0.358	0.395	9.708	16.396	17.840	17.724
1997	0.471	0.209	0.325	0.422	10.416	15.509	18.019	17.610
1998	0.505	0.284	0.401	0.487	9.483	17.137	19.980	19.402
1999	0.628	0.386	0.517	0.645	9.612	15.167	18.538	19.389
2000	0.760	0.529	0.682	0.807	8.238	12.265	14.507	16.251
2001	0.857	0.738	0.825	0.899	6.866	11.599	14.141	15.518
2002	0.754	0.504	0.668	0.808	8.087	12.135	13.701	15.102
2003	0.724	0.428	0.622	0.807	8.465	11.981	14.311	16.914
2004	0.587	0.201	0.412	0.626	10.220	13.519	15.299	16.364
2005	0.473	0.259	0.347	0.409	10.459	16.275	18.299	18.089
2006	0.434	0.208	0.310	0.395	10.168	16.469	18.750	19.274
2007	0.667	0.530	0.592	0.649	7.780	15.724	18.708	19.137
2008	0.826	0.721	0.788	0.848	7.016	13.893	17.195	18.693
2009	0.716	0.464	0.630	0.768	8.970	13.448	16.043	17.009
2010	0.648	0.294	0.508	0.701	9.306	13.050	15.066	16.297
Average					9.460	13.958	16.123	16.969

Table 6a. Sardine proportion-at-age (by number) and weight-at-age (in grams) in the November survey for the full area (one stock).

	Proportion-at-Age					Weight-at-Age				
Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 1	Age 2	Age 3	Age 4	Age 5
1993	0.528	0.230	0.161	0.050	0.031	37.254	69.736	74.850	100.685	118.476
1994	0.229	0.188	0.249	0.162	0.172	46.851	69.253	81.051	87.699	92.706
1996	0.222	0.362	0.154	0.074	0.188	55.382	83.662	109.836	117.766	117.766
2001	0.820	0.053	0.077	0.033	0.018	25.504	64.847	77.444	94.547	94.547
2002	0.338	0.246	0.210	0.125	0.080	27.985	62.753	74.848	84.715	93.621
2003	0.550	0.191	0.096	0.101	0.063	39.279	65.435	77.581	79.712	84.280
2004	0.321	0.209	0.247	0.129	0.095	41.239	84.260	94.863	104.228	112.998
2006	0.740	0.067	0.055	0.071	0.066	45.395	73.641	87.892	95.543	101.883
2007	0.724	0.173	0.049	0.026	0.029	54.193	81.465	90.886	81.836	103.084
2008	0.923	0.072	0.004	0.001	0.001	33.161	46.649	77.251	96.556	96.556
2009	0.792	0.093	0.066	0.037	0.013	30.370	72.936	83.931	88.459	96.738
Average (93-96,06-09)						43.229	71.049	86.528	95.506	103.887
Average (01-04)						33.502	69.324	81.184	90.801	96.361

Table 6b. Sardine proportion-at-age (by number) and weight-at-age (in grams) in the November survey west of Cape Agulhas.

	Proportion-at-Age					Weight-at-Age				
Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 1	Age 2	Age 3	Age 4	Age 5
1993	0.420	0.344	0.181	0.033	0.022	35.598	73.875	72.822	111.681	123.518
1994	0.237	0.176	0.265	0.152	0.169	43.045	67.099	78.456	81.929	90.912
1996	0.083	0.537	0.180	0.157	0.044	38.343	59.669	71.670	85.982	107.678
2001	0.900	0.034	0.033	0.006	0.026	21.613	48.773	65.380	74.071	94.024
2002	0.518	0.308	0.103	0.049	0.022	29.369	49.304	61.408	77.496	87.503
2003	0.847	0.105	0.035	0.010	0.004	38.328	49.880	56.871	74.041	90.222
2004	0.556	0.243	0.168	0.027	0.005	38.203	60.167	71.041	82.656	88.337
2006	0.867	0.096	0.035	0.001	0.001	51.982	67.749	76.259	95.993	95.993
2007	0.943	0.030	0.021	0.003	0.003	53.944	70.165	75.573	94.747	94.747
2008	0.948	0.045	0.006	0.001	0.001	30.611	48.048	78.667	104.531	104.531
2009	0.834	0.081	0.050	0.026	0.009	24.981	71.710	82.748	83.888	88.870
Average (93-96,06-09)						39.786	65.474	76.599	94.107	100.893
Average (01-04)						31.878	52.031	63.675	77.066	90.022

Table 6c. Sardine proportion-at-age (by number) and weight-at-age (in grams) in the November survey east of Cape Agulhas.

	Proportion-at-Age					Weight-at-Age				
Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 1	Age 2	Age 3	Age 4	Age 5
1993	0.765	0.117	0.072	0.031	0.015	34.686	54.131	72.322	95.091	116.462
1994	0.169	0.152	0.224	0.229	0.226	60.375	73.601	89.307	98.173	102.231
1996	0.354	0.204	0.059	0.024	0.360	91.345	132.838	176.034	199.687	199.687
2001	0.790	0.054	0.098	0.034	0.024	26.467	74.822	81.455	94.221	97.196
2002	0.209	0.228	0.290	0.166	0.107	24.715	74.217	78.636	87.525	97.878
2003	0.242	0.165	0.493	0.060	0.040	36.579	67.501	80.121	95.428	99.656
2004	0.257	0.202	0.241	0.168	0.133	40.654	89.857	95.803	106.708	113.418
2006	0.674	0.085	0.059	0.095	0.086	40.564	67.217	91.829	97.424	104.363
2007	0.617	0.268	0.045	0.037	0.034	48.252	75.540	94.839	80.168	102.644
2008	0.393	0.212	0.279	0.117	0.000	31.025	38.312	40.430	53.502	53.502
2009	0.734	0.099	0.092	0.057	0.018	40.959	75.213	85.323	92.753	104.315
Average (93-96,06-09)						49.601	73.836	92.869	102.400	111.886
Average (01-04)						32.104	76.599	84.004	95.970	102.037

Table 8. 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	348.612	368.623	0.263	4.177	83.458	37.568	38.265	0.596	10.426	3.603					
1986	617.468	621.089	0.183	4.433	139.299	47.241	50.073	0.594	12.739	3.708					
1987	676.727	721.578	0.163	5.438	124.442	97.559	98.643	0.598	12.101	8.062					
1988	561.409	563.107	0.163	4.352	129.010	4.416	5.223	0.402	10.138	0.436					
1989	161.526	173.349	0.201	4.875	33.136	50.525	66.081	0.616	22.413	2.254					
1990	169.597	170.083	0.225	3.315	51.153	27.483	31.208	0.907	11.010	2.496					
1991	519.847	528.177	0.149	4.577	113.580	22.765	26.665	0.276	11.957	1.904					
1992	428.099	458.455	0.166	4.568	93.712	68.140	74.822	0.325	12.190	5.590					
1993	448.329	481.108	0.259	3.896	115.072	111.184	114.956	0.358	7.204	15.434					
1994	107.915	145.336	0.180	3.531	30.565	58.378	72.462	0.311	21.629	2.699	0.020	30.263	0.562	28.011	6.517
1995	391.598	392.016	0.178	3.547	110.400	199.591	205.149	0.345	7.664	26.042	0.005	4.606	0.417	19.156	0.235
1996	72.170	74.842	0.222	2.802	25.757	65.632	73.612	0.370	18.595	3.530					
1997	404.473	404.620	0.185	4.474	90.401	380.090	396.718	0.420	9.415	40.372					
1998	451.510	453.210	0.149	3.310	136.520	124.952	134.907	0.354	11.660	10.716					
1999	813.098	826.090	0.158	4.081	199.228	220.589	235.720	0.378	21.255	10.378	58.613	75.966	0.585	45.419	1.290
2000	2477.589	2553.502	0.170	3.966	624.675	265.489	299.473	0.359	13.273	20.002	168.591	175.175	0.503	31.870	5.290
2001	2027.740	1998.427	0.134	3.233	627.200	553.538	573.427	0.285	9.216	60.065	0.005	0.008	0.695	9.932	0.000
2002	1541.803	1560.101	0.115	2.963	520.413	610.344	616.331	0.183	12.417	49.153	41.495	83.139	0.960	31.103	1.334
2003	1391.468	1434.900	0.190	3.234	430.308	508.911	600.667	0.217	13.963	36.448	19.948	34.522	0.512	43.572	0.458
2004	1060.548	1071.419	0.223	4.445	238.569	25.871	40.419	0.324	6.326	4.089	4.187	75.454	0.794	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 8 (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	299.833	0.269	3.029	176.917	16.736	11.236	0.303	5.823	2.874	20.658	86.705	0.593	19.357	1.067
2006	259.194	275.797	0.182	2.207	117.465	49.926	50.394	0.379	5.220	9.564	62.564	71.332	0.579	17.721	3.530
2007	1499.082	1534.523	0.183	2.959	506.703	29.689	34.575	0.342	10.110	2.937	17.985	34.505	0.757	13.506	1.332
2008	1432.841	1491.847	0.202	2.544	563.156	20.555	24.461	0.325	5.336	3.852					
2009	1307.613	1317.059	0.188	3.598	363.387	57.739	63.468	0.679	6.271	9.210	64.360	64.193	1.007	17.762	3.623
2010	1667.695	1687.118	0.265	4.351	383.328	477.437	499.986	0.458	13.423	35.569	6.407	9.042	0.906	20.077	0.319

* Data to which the assessments are tuned.

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

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

MCM data

- 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.

Observer data

- 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.

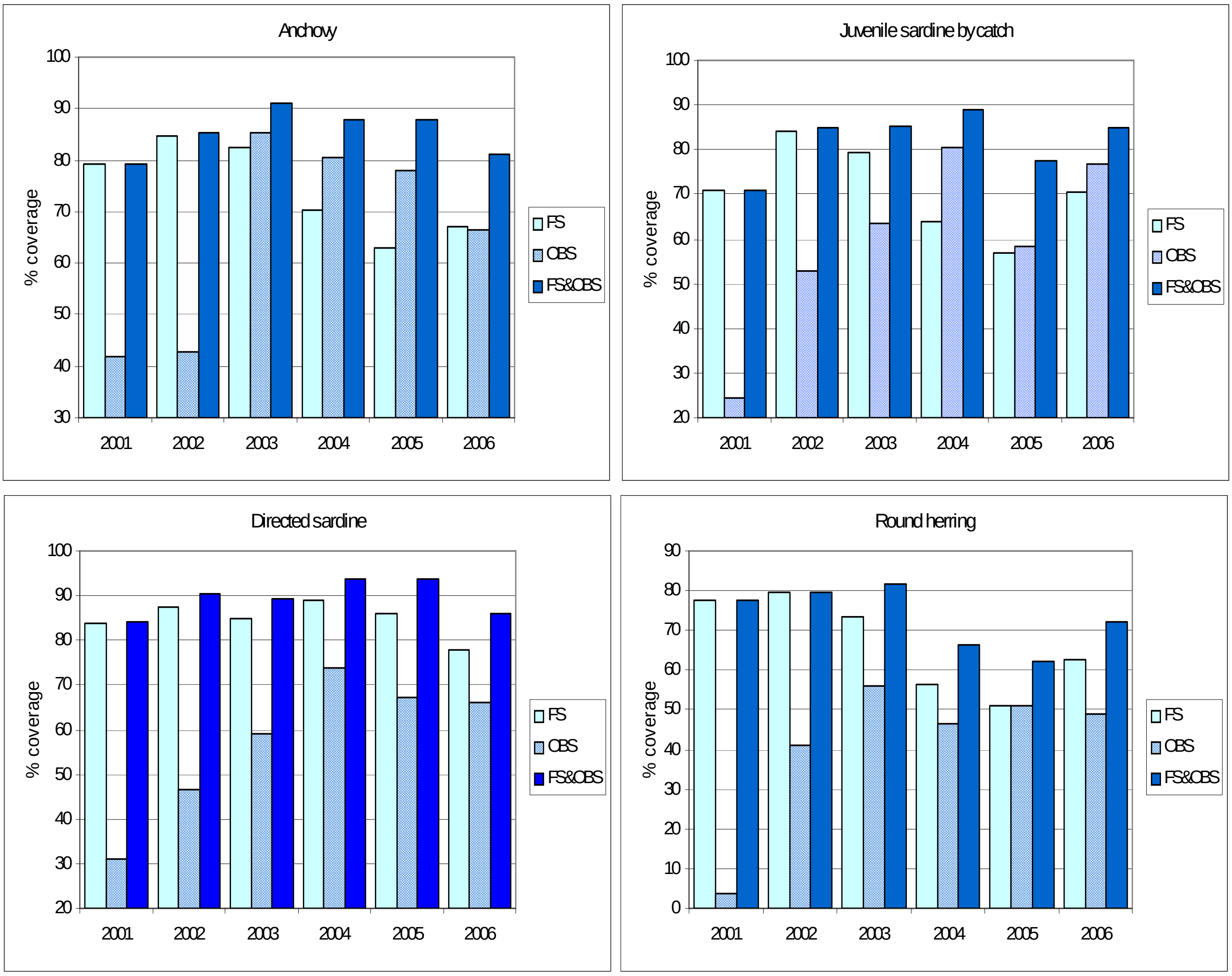

Figure A.1. Coverage obtained on a first level pool-area/week for the field stations (FS), the observers (OBS) and a combination of the two (FS&OBS).

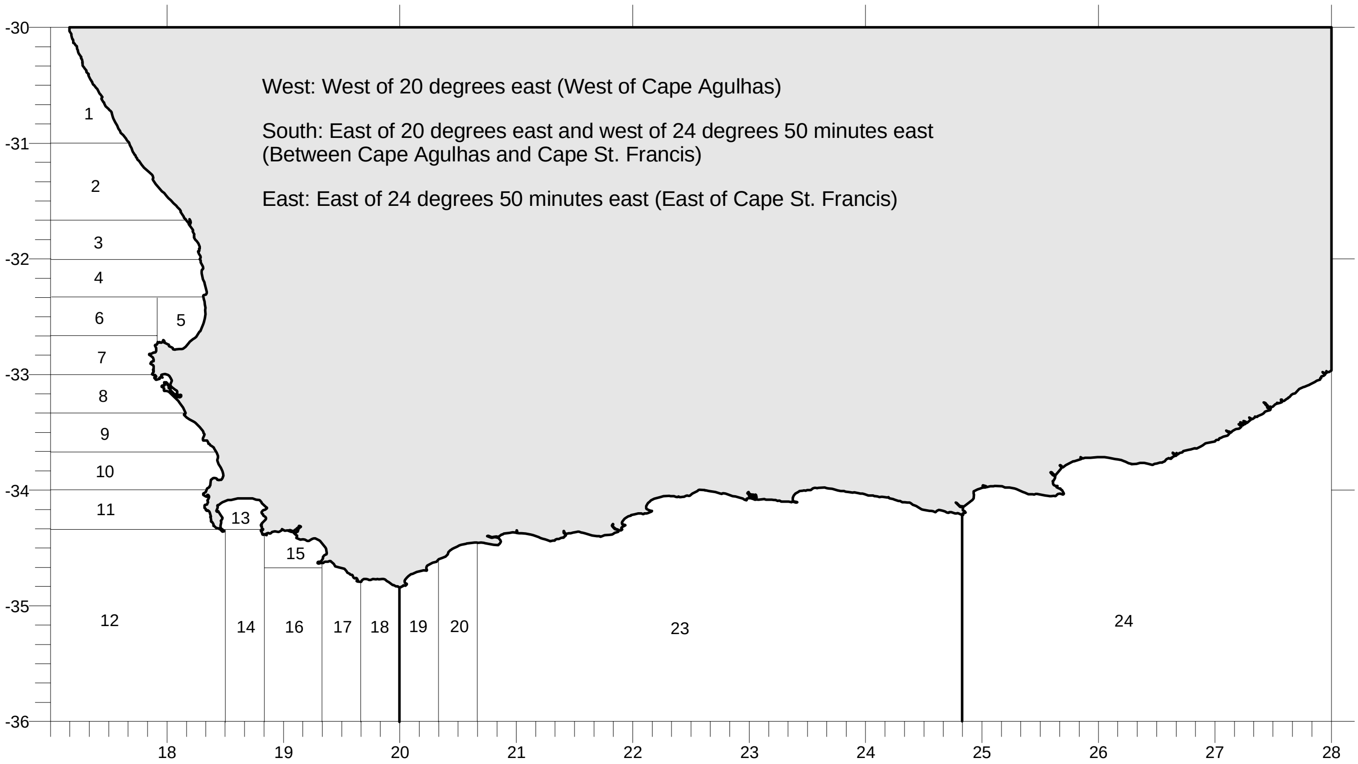

Figure A.2. The pool areas that are used for sample allocation and the three larger areas that are used for the OMP revision.

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) $=\mathrm{W_{GR}(grid,stratum,species)/LFMASS}$. 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.