A Record of the Generation of Data Used in the 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 to be used in the anchovy and sardine assessments to be carried out in 2007. 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. From 1987-2006, RLFs are available by Western (west of Cape Agulhas), Southern (Cape Agulhas to Cape St. Francis) and Eastern (east of Cape St. Francis) areas. Between 1984 and 1986, 31 pelagic catch positions were recorded outside of the Western area. With the exclusion of one catch position (5103 in pool area 20, see Figure A.2) in the Southern area (only just outside the Western area) in 1986, all the recorded positions were east of East London. The only vessels that could possibly have fished in those areas during the 1980s would have been small bait boats targeting sardine only. The landings recorded outside of the Western area were from vessels that were all equipped with power blocks and suction pumps and they would not have been able to land fish of the quantities in question on the east coast. These vessels were bigger than the bait boats and it is therefore highly unlikely that these catch positions are correct. Apart from one digit the four-number positions are all the same as positions on the west coast, leading us to believe that these were punching errors. The one throw in 5103 in 1986 was most probably sardine, not anchovy, and thus all the anchovy catch from 1984 to 1986 was assumed to occur in the Western area.

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:

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

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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
1990	August	215t	Western	July 1990	558t
1990	September	34t	Western	July 1990	558t
1993	December	64t	Western	November 1993	7t
1996	November	18t	Western	October 1996	21t
2005	December	27t	Western	November 2005	1950t

The RLFs by month from 1984 to 1986 and also by area from 1987 to 2006 are stored in *Anchovy RLFs with Cut-Offs.xls*.

Splitting Juvenile and Adult Catch

The following cut-off lengths (Cunningham and Butterworth 2007) were applied to each month and area to calculate the number of juveniles and adults from 1984 to 2006:

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

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*.

Catch Weight

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 2006. These data are recorded in *Anchovy RLFs with Cut-Offs.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: $AM_{l,m,a} = \frac{EM_{l,m,a}}{\sum_l EM_{l,m,a}} \times ObsT_{m,a}$

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

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

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

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

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-Offs.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 and thus annual catch weight-at-age for juveniles between 1981 and 1983 and for adults between 1982 and 1983 was taken from De Oliveria (2003).

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 page 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-Offs.xls* and *Survey Data.xls*.

Sardine Commercial Data

ALKs for sardine commercial catch for some months each year from 1984 to 1999 were derived by Michael Kerstan (De Oliveria 2003). As the priority for sardine ageing has been on November surveys rather than commercial catch, only three commercial ALKs have been derived by Deon Durholtz (see Table B.1). Due to inconsistencies between the ALKs from both readers (see Appendix B), it was decided that only ALKs from Deon Durholtz would be used in the assessments (although see below for later recommendation not to use ageing data in the assessment).

In the absence of sufficient sardine commercial ALKs, proportions-at-length computed directly from the commercial RLFs were used. These RLFs were available by month between 1984 and 1986 and by area and month between 1987 and 2006 and are stored in *Sardine RLF 1984 1986.xls* and *Sardine RLF NewArea 1987 2006.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 last assessment in 2004. The commercial data were grouped by quarter and a maximum of 7 length groups. In some quarters the proportion-at-length in a given length group was very small, prompting the combination of length groups. In 1984-1986 and 1989 the percentage of the total tonnage landed in quarter 4 was < 4% and thus the assessment model was not fit to the proportions-at-length in quarter 4 for these four years. The proportions-at-length are given in Table 3 together with the tonnage landed each quarter.

Juvenile catch prior to the survey

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. In previous assessments, a cut-off length of ≤15cm was used for all years. Recently, however, the estimates of recruitment from the May survey from 1997 to 2006 were updated using a revised cut-off length varying between years, based on a modal progression analysis (Coetzee and Merkle 2007). To maintain consistency, the cut-off lengths used to calculate the recruit survey biomass were therefore also applied to the calculation of the recruit catch between 1 May and the day before the survey commenced. These data are stored in *Sardine Juv Catch Before Survey.xls* and given in Table 2.

November Survey Data

The time series of 1+ biomass estimates from the acoustic surveys in November each year has been updated using a new target strength expression and, in the case of sardine, taking attenuation into account (Coetzee *et al*. 2007). Uncapped (with attenuation in the case of sardine) data prior to 1997 were obtained from calibration against capped data without attenuation (Cunningham *et al*. 2007). The new 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).

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 2006 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 are available only for 1993, 1994, 1996, 2001, 2002, 2003, 2004 and 2006. These have been derived by Deon Durholtz and are stored in *SardineNovALKs.xls*. 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. Details on the sardine ageing process are given in Appendix B. These ALKs were used to calculate the proportion-at-age and weight-at-age in the November survey (Table 6). There is evidence that the ALK under-represents sardine of age 1 in the survey and thus a bias factor needs to be included in the assessment to account for this (see Appendix B). 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). 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.

All the above survey data are stored in *SurveyData.xls*, with finer details on the calibration of uncapped biomass from capped biomass in *SardineNovCalibration.xls* and *AnchovyNovCalibration.xls*.

The proportion at length in 7 length classes was determined from the November survey length frequencies. These proportions-at-length provide additional growth information in the years for which ageing data are unavailable. The data are given in Table 7 and stored in *November RLFs.xls*.

The NRF/SA Pelagic and Rock Lobster Industries International Stock Assessment Workshop held in Cape Town in July 2007 recommended that the November survey age- and length-composition data be excluded from the likelihood function for the sardine assessment for 2007. This was primarily due to the inability to see consistent indications of good or poor year-classes in both the length- and the age-composition data. A thorough review of the sampling scheme for collection of length-frequency data from the hydroacoustic surveys was also recommended in addition to quantifying the uncertainty associated with these data.

Recruit Survey Data

The time series of recruitment estimates from the acoustic surveys in May/June each year has been updated using a new target strength expression and, in the case of sardine, taking attenuation into account (Coetzee *et al*. 2007). Uncapped (with attenuation in the case of sardine) data prior to 1997 were obtained from calibration against capped data without attenuation (Cunningham *et al*. 2007). The new 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 C. 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 before the next assessment. In the assessments, the recruit numbers are used together with the CVs on recruit biomass.

All the above survey data are stored in *SurveyData.xls*, with finer details on the calibration of uncapped biomass from capped biomass in *SardineMayCalibration.xls* and *AnchovyMayCalibration.xls*.

References

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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 numbers) and mean catch weight (in kilograms). 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**
1981	178633*	113316*	0.0079*	-
1982	199079*	107082*	0.0058*	0.0108*
1983	164121*	27425*	0.0070*	0.0106*
1984	29987537	9416485	0.0057	0.0102
1985	32687599	8544017	0.0052	0.0111
1986	50114319	6250229	0.0045	0.0116
1987	28038404	34024541	0.0065	0.0123
1988	48450985	21236966	0.0057	0.0138
1989	19000666	14283375	0.0064	0.0123
1990	32169066	1117853	0.0043	0.0120
1991	24742109	1474539	0.0055	0.0100
1992	59420844	7873901	0.0043	0.0122
1993	31856839	9228806	0.0041	0.0115
1994	21611587	5469886	0.0044	0.0113
1995	40036305	1631826	0.0040	0.0093
1996	6141948	1417886	0.0048	0.0093
1997	12014815	60026	0.0050	0.0130
1998	21877746	763655	0.0045	0.0111
1999	35061348	428159	0.0050	0.0110
2000	45940811	2839358	0.0051	0.0114
2001	55658108	2651615	0.0047	0.0096
2002	43361634	3339933	0.0042	0.0104
2003	62090898	1167115	0.0039	0.0117
2004	39136380	1604959	0.0045	0.0090
2005	32838364	8917360	0.0058	0.0105
2006	29487772	1330591	0.0041	0.0109

* These data are not used in the assessment.

Table 2. The date of the commencement of the annual recruit survey; juvenile anchovy catch (in numbers) and mean catch weight of individual fish (in kilograms) 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	Juvenile anchovy catch prior to 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
1985	20-May	0.613	14446081	0.0058	15.0	7318000
1986	10-Jun	1.300	21077845	0.0074	15.0	8971000
1987	20-Jul	2.613	13610181	0.0067	15.0	63464000
1988	27-Jun[1]	1.867	12445201	0.0054	15.5	194929000
1989	08-Jun[2]	1.233	12420888	0.0069	15.5	45282000
1990	22-Jun	1.700	31131308	0.0043	15.5	10499000
1991	07-May	0.194	12327687	0.0054	15.5	8518000
1992	13-May	0.387	12865144	0.0039	15.5	29171000
1993	21-May	0.645	1211617	0.0058	15.5	45048000
1994	05-May	0.129	4234179	0.0041	15.5	72884000
1995	10-Jun	1.300	12511225	0.0044	15.5	161119000
1996	05-Jun	1.133	4051491	0.0050	15.5	81362000
1997	17-May	0.516	166349	0.0065	13.5	35419000
1998	20-May	0.613	6083460	0.0051	13.5	424298000
1999	10-May	0.290	1843042	0.0052	16.5	25231000
2000	15-May	0.452	8120212	0.0061	16.5	86717000
2001	05-May	0.129	5802894	0.0058	11.5	330000
2002	05-May	0.129	1620008	0.0062	15.5	36846000
2003	14-May	0.419	3066935	0.0049	15.5	87499000
2004	08-May	0.226	3870663	0.0056	13.5	35994000
2005	13-May	0.387	4292109	0.0064	13.0	100522000
2006	19-May	0.581	907536	0.0051	14.5	37312000

[1] The first station was on 27th June 1988, although the first acoustic interval was only logged after midnight, i.e. on 28th June 1988.
[2] 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 3. The quarterly proportion-at-length (by number) in the sardine commercial catch. The quarters of the year are as follows: 1: November-January, 2: February-April, 3: May-July, 4: August-October. In some cases length groups are combined. This is indicated by "-1" in the larger of the combined length groups. No data from quarter 4 in 1984 - 1986 and 1989 are used in the assessment model. The tonnage landed each quarter is given in the right hand column.

Year	Quarter	l < 10.5cm	10.5cm ≤ l < 14cm	14cm ≤ l < 17.5cm	17.5cm ≤ l < 18.5cm	18.5cm ≤ l < 19.5cm	19.5cm ≤ l	Tonnage
1984	1	0.373	-1	0.522	0.062	0.024	0.019	1980
	2	0.068	0.206	0.482	0.134	0.063	0.047	18297
	3	0.198	0.072	0.724	-1	-1	0.006	6485
	4	-1	-1	-1	-1	-1	-1	261
1985	1	0.534	-1	0.198	0.18	0.08	0.007	3641
	2	0.599	0.133	0.055	0.097	0.079	0.036	16168
	3	0.844	0.139	0.011	-1	-1	0.005	10878
	4	-1	-1	-1	-1	-1	-1	25
1986	1	0.061	-1	0.155	0.193	0.288	0.304	1310
	2	0.469	0.231	0.069	0.066	0.089	0.077	19496
	3	0.652	0.252	0.088	-1	-1	0.008	9611
	4	-1	-1	-1	-1	-1	-1	222
1987	1	0.002	-1	0.253	0.291	0.313	0.142	3693
	2	0.062	0.243	0.124	0.155	0.225	0.191	20853
	3	0.766	0.116	0.071	-1	-1	0.049	7083
	4	0.794	0.187	0.014	-1	-1	0.006	1895
1988	1	0.05	-1	0.392	0.135	0.155	0.267	1855
	2	0.087	0.055	0.244	0.105	0.174	0.333	14405
	3	0.729	0.078	0.078	-1	-1	0.115	14812
	4	0.497	0.316	0.09	-1	-1	0.096	3450
1989	1	0.381	-1	0.258	0.067	0.1	0.195	3311
	2	0.202	0.415	0.071	0.023	0.033	0.258	19412
	3	0.76	0.135	0.022	-1	-1	0.082	12517
	4	-1	-1	-1	-1	-1	-1	989
1990	1	0.317	-1	0.108	0.042	0.04	0.494	3341
	2	0.565	0.099	0.051	0.036	0.029	0.22	22182
	3	0.802	0.015	0.067	-1	-1	0.116	23767
	4	0.008	-1	-1	0.047	0.144	0.802	7570
1991	1	0.122	-1	0.149	0.17	0.195	0.365	3389
	2	0.688	0.063	0.032	0.033	0.063	0.122	21122
	3	0.431	0.16	0.236	-1	-1	0.174	21765
	4	0.024	-1	-1	0.089	0.413	0.474	6911
1992	1	0.135	-1	0.259	0.051	0.176	0.379	1569
	2	0.506	0.139	0.099	0.03	0.079	0.148	17577
	3	0.813	0.094	0.034	-1	-1	0.06	18961
	4	0.575	0.186	0.04	0.018	0.056	0.124	16068
1993	1	0.086	-1	0.277	0.152	0.19	0.295	6288
	2	0.216	0.125	0.198	0.114	0.133	0.213	21683
	3	0.628	0.152	0.051	0.042	0.049	0.078	15396
	4	0.89	0.036	0.019	0.017	0.014	0.023	5768
1994	1	0.331	-1	0.236	0.221	0.145	0.067	5411
	2	0.254	0.283	0.214	0.078	0.086	0.085	31747
	3	0.614	0.115	0.115	0.047	0.051	0.057	37418
	4	0.42	0.117	0.091	0.096	0.151	0.125	21673

Year	Quarter	l < 10.5cm	10.5cm ≤ l < 14cm	14cm ≤ l < 17.5cm	17.5cm ≤ l < 18.5cm	18.5cm ≤ l < 19.5cm	19.5cm ≤ l	Tonnage
1995	1	0.238	-1	0.127	0.157	0.282	0.196	5126
	2	0.455	-1	0.047	0.098	0.204	0.195	26617
	3	0.868	-1	0.031	0.041	0.041	0.019	38335
	4	0.802	-1	0.032	0.031	0.064	0.071	45869
1996	1	0.766	-1	0.056	0.029	0.052	0.098	11176
	2	0.547	-1	0.14	0.035	0.056	0.222	30847
	3	0.658	-1	0.09	0.066	0.076	0.109	29914
	4	0.005	-1	0.254	0.199	0.231	0.313	28372
1997	1	0.098	-1	0.231	0.183	0.219	0.27	16112
	2	0.016	-1	0.214	0.188	0.304	0.278	32986
	3	0.454	-1	0.097	0.114	0.197	0.138	38717
	4	0.607	-1	0.104	0.114	0.112	0.063	42740
1998	1	0.09	-1	0.295	0.205	0.238	0.172	5955
	2	0.513	-1	0.143	0.099	0.126	0.119	33096
	3	0.768	-1	0.039	0.057	0.079	0.056	46689
	4	0.27	-1	0.063	0.161	0.277	0.228	45754
1999	1	0.002	-1	0.143	0.122	0.297	0.435	8285
	2	0.361	-1	0.17	0.166	0.15	0.152	12713
	3	0.458	-1	0.135	0.131	0.156	0.119	41157
	4	0.34	-1	0.211	0.178	0.174	0.097	40160
2000	1	0.017	-1	0.148	0.207	0.36	0.268	34950
	2	0.548	-1	0.077	0.119	0.147	0.109	25830
	3	0.369	-1	0.148	0.208	0.19	0.084	47350
	4	0.073	-1	0.157	0.27	0.325	0.175	43731
2001	1	0.005	-1	0.239	0.289	0.307	0.159	20689
	2	0.207	-1	0.159	0.237	0.281	0.115	44025
	3	0.641	-1	0.095	0.12	0.11	0.034	38669
	4	0.557	-1	0.063	0.097	0.163	0.12	50219
2002	1	0.04	-1	0.22	0.252	0.301	0.187	56332
	2	0.147	-1	0.403	0.163	0.191	0.097	56611
	3	0.536	-1	0.262	0.075	0.089	0.038	41703
	4	0.483	-1	0.238	0.102	0.11	0.066	81092
2003	1	0.083	-1	0.428	0.219	0.177	0.093	85797
	2	0.26	-1	0.378	0.163	0.133	0.067	84535
	3	0.53	-1	0.293	0.066	0.07	0.04	63896
	4	0.218	-1	0.414	0.152	0.137	0.079	51898
2004	1	0.045	-1	0.596	0.216	0.099	0.044	94181
	2	0.083	-1	0.605	0.168	0.099	0.046	99331
	3	0.299	-1	0.508	0.057	0.069	0.066	97132
	4	0.128	-1	0.332	0.246	0.19	0.105	82743
2005	1	0.079	-1	0.422	0.33	0.134	0.036	86266
	2	0.114	-1	0.391	0.294	0.144	0.058	90401
	3	0.224	-1	0.146	0.176	0.254	0.2	74368
	4	0.154	-1	0.057	0.142	0.351	0.296	51286
2006	1	0.101	-1	0.16	0.267	0.355	0.117	32324
	2	0.093	-1	0.303	0.211	0.256	0.137	55581
	3	0.482	-1	0.014	0.045	0.202	0.256	79781
	4	0.384	-1	0.269	0.128	0.125	0.093	49929

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**	
Year	**Sardine 1+ Biomass (t)**	**CV**	**Anchovy 1+ Biomass (t)**	**CV**	**Anchovy 1+ Biomass (t)**	**CV**
1984	48378	1.118	1553813	0.282	1100000	0.45
1985	45013	0.509	1366294	0.211	616000	0.4
1986	299797	0.848	2568625	0.172	2001000	0.35
1987	111285	0.630	2108771	0.157	1606000	0.3
1988	134362	0.957	1607060	0.222	1679000	0.35
1989	256655	0.274	751529	0.167	421000	0.35
1990	289876	0.352	651711	0.183	723000	0.58
1991	597858	0.395	2327834	0.159	2913000	0.35
1992	494157	0.658	2088025	0.161		
1993	560019	0.427	916359	0.209		
1994	518354	0.370	617276	0.159		
1995	843944	0.713	601271	0.217		
1996	529456	0.471	162048	0.410		
1997	1224632	0.329	1482633	0.267		
1998	1607328	0.251	1229132	0.217		
1999	1635410	0.212	2052156	0.156		
2000	2292380	0.500	4653779	0.125		
2001	2309600	0.142	6720287	0.107		
2002	4206250	0.227	3867649	0.154		
2003	3564171	0.197	3563232	0.236		
2004	2615715	0.334	2044615	0.131		
2005	1048991	0.300	3077001	0.144		
2006	712553	0.346	2106273	0.136		

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	0.421	0.051	0.124	0.369	12.7967	15.1490	16.6183	17.2049
1985	0.474	0.103	0.256	0.484	11.4338	14.7791	17.0286	17.3830
1986	0.667	0.390	0.587	0.713	10.0258	14.1286	16.2672	17.3341
1987	0.715	0.450	0.646	0.775	9.9953	14.0492	16.4220	17.7702
1988	0.634	0.219	0.522	0.738	10.2863	13.0913	15.3454	16.8259
1989	0.350	0.043	0.061	0.187	12.4737	14.3780	15.4066	15.6206
1990	0.738	0.498	0.663	0.817	8.8263	13.5242	16.1787	17.7034
1991	0.723	0.443	0.636	0.791	8.3986	12.0700	14.0414	15.2857
1992	0.614	0.297	0.445	0.646	9.0193	12.6175	13.9969	14.9787
1993	0.544	0.189	0.334	0.553	9.6323	12.6475	14.1798	14.8984
1994	0.401	0.116	0.223	0.327	11.0979	14.6162	15.8963	16.0669
1995	0.734	0.574	0.678	0.761	7.0242	11.2680	13.5630	14.1617
1996	0.478	0.333	0.358	0.395	9.8544	16.4071	17.8522	17.7359
1997	0.459	0.209	0.325	0.422	10.6761	15.5295	18.0426	17.6288
1998	0.492	0.284	0.401	0.487	9.6534	17.1476	19.9926	19.4141
1999	0.623	0.386	0.517	0.645	9.6565	15.2010	18.5798	18.1263
2000	0.756	0.536	0.688	0.810	8.1297	12.0844	14.3077	15.2810
2001	0.837	0.738	0.825	0.899	6.9208	11.5988	14.1412	15.5176
2002	0.733	0.504	0.668	0.808	8.2220	12.1350	13.7013	15.1019
2003	0.718	0.428	0.622	0.807	8.4868	11.9808	14.3110	16.9137
2004	0.580	0.201	0.412	0.626	10.3044	13.5189	15.2994	16.3643
2005	0.470	0.259	0.347	0.409	10.4821	16.2745	18.2994	18.0890
2006	0.428	0.210	0.313	0.399	10.2574	16.4692	18.7499	19.2740
Average					9.7241	13.9420	16.0096	16.7252

Table 6. Sardine proportion-at-age (by number) and weight-at-age (in grams) in the November survey.

	Proportion-at-Age[3]					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	0.098	0.473	0.216	0.153	0.060	25.483	39.937	74.304	77.632	110.329
1994	0.023	0.361	0.269	0.199	0.149	42.281	61.340	81.786	89.778	96.285
1996	0.130	0.346	0.295	0.145	0.084	31.515	67.920	92.792	108.538	124.788
2001	0.525	0.342	0.039	0.058	0.035	19.896	29.992	72.327	82.142	95.360
2002	0.128	0.271	0.231	0.193	0.174	22.750	33.187	66.103	77.252	88.508
2003	0.505	0.197	0.148	0.099	0.050	38.804	53.252	81.420	93.045	105.959
2004	0.323	0.143	0.228	0.162	0.139	20.408	57.433	80.811	86.814	96.115
2006	0.732	0.049	0.030	0.020	0.011	30.232	65.055	85.564	94.835	103.858
Average (93,94,96,06)						32.378	58.563	83.612	92.696	108.815
Average (01-04)						25.464	43.466	75.165	84.813	96.486

[3] These proportions-at-age do not add up to 1 due to a small observed proportion-at-age 0. These proportions are re-normalised before use in the assessment.

Table 7. Sardine proportion-at-length (by number) in the November survey for years for which ALKs are not yet available.

Year	l < 11.5cm	11.5cm ≤ l < 13cm	13cm ≤ l < 14.5cm	14.5cm ≤ l < 15.5cm	15.5cm ≤ l < 17.5cm	17.5cm ≤ l < 19cm	19cm ≤ l
1984	0.095	0.034	0.084	0.095	0.565	0.102	0.024
1985	0.020	0.116	0.333	0.233	0.138	0.069	0.091
1986	0.002	0.176	0.631	0.065	0.037	0.071	0.017
1987	0.090	0.158	0.216	0.040	0.104	0.076	0.316
1988	0.017	0.045	0.220	0.219	0.287	0.116	0.096
1989	0.078	0.019	0.154	0.201	0.164	0.150	0.235
1990	0.017	0.064	0.133	0.060	0.215	0.149	0.363
1991	0.083	0.199	0.259	0.165	0.070	0.069	0.155
1992	0.025	0.106	0.263	0.360	0.178	0.034	0.035
1995	0.133	0.246	0.114	0.012	0.070	0.091	0.334
1997	0.035	0.127	0.097	0.034	0.175	0.386	0.145
1998	0.164	0.149	0.266	0.081	0.067	0.084	0.188
1999	0.002	0.060	0.159	0.150	0.276	0.177	0.175
2000	0.032	0.063	0.239	0.164	0.171	0.058	0.273
2005	0.111	0.053	0.103	0.111	0.116	0.141	0.365

Table 8. Sardine and anchovy recruitment (in tons and in billions) up to Cape Infanta and associated CV from the recruitment acoustic survey. The mean recruit weight is also given (in grams).

	Anchovy					Sardine				
Year	Biomass	CV*	Biomass	Mean Weight	Numbers*	Biomass	CV*	Biomass	Mean Weight	Numbers*
1985	368.623	0.263	348.612	4.177	83.458	38.265	0.596	37.568	10.426	3.603
1986	621.089	0.183	617.468	4.433	139.299	50.073	0.594	47.241	12.739	3.708
1987	721.578	0.163	676.727	5.438	124.442	98.643	0.598	97.559	12.101	8.062
1988	563.107	0.163	561.409	4.352	129.010	5.223	0.402	4.416	10.138	0.436
1989	173.349	0.201	161.526	4.875	33.136	66.081	0.616	50.525	22.413	2.254
1990	170.083	0.225	169.597	3.315	51.153	31.208	0.907	27.483	11.010	2.496
1991	528.177	0.149	519.847	4.577	113.580	26.665	0.276	22.765	11.957	1.904
1992	458.455	0.166	428.099	4.568	93.712	74.822	0.325	68.140	12.190	5.590
1993	481.108	0.259	448.329	3.896	115.072	114.956	0.358	111.184	7.204	15.434
1994	145.336	0.180	107.915	3.531	30.565	72.462	0.311	58.378	21.629	2.699
1995	392.016	0.178	391.598	3.547	110.400	205.149	0.345	199.591	7.664	26.042
1996	74.842	0.222	72.170	2.802	25.757	73.612	0.370	65.632	18.595	3.530
1997	404.620	0.185	404.473	4.474	90.401	396.718	0.420	385.792	9.516	40.539
1998	453.210	0.149	451.510	3.310	136.520	134.907	0.354	124.952	11.660	10.716
1999	826.090	0.158	813.098	4.081	199.228	235.720	0.378	220.589	21.255	10.378
2000	2553.502	0.170	2477.589	3.966	624.675	299.473	0.359	265.489	13.273	20.002
2001	1998.427	0.134	2027.740	3.233	627.200	573.427	0.285	553.538	9.216	60.065
2002	1560.101	0.115	1541.803	2.963	520.413	616.331	0.183	610.344	12.417	49.153
2003	1434.900	0.190	1391.468	3.234	430.308	600.667	0.217	508.911	13.963	36.448
2004	1071.419	0.223	1060.548	4.445	238.569	40.419	0.324	25.871	6.326	4.089
2005	299.833	0.269	535.958	3.029	176.917	11.236	0.303	16.736	5.823	2.874
2006	275.797	0.182	259.194	2.207	117.465	50.394	0.379	49.926	5.220	9.564

* Data to which the assessments are tuned.

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.

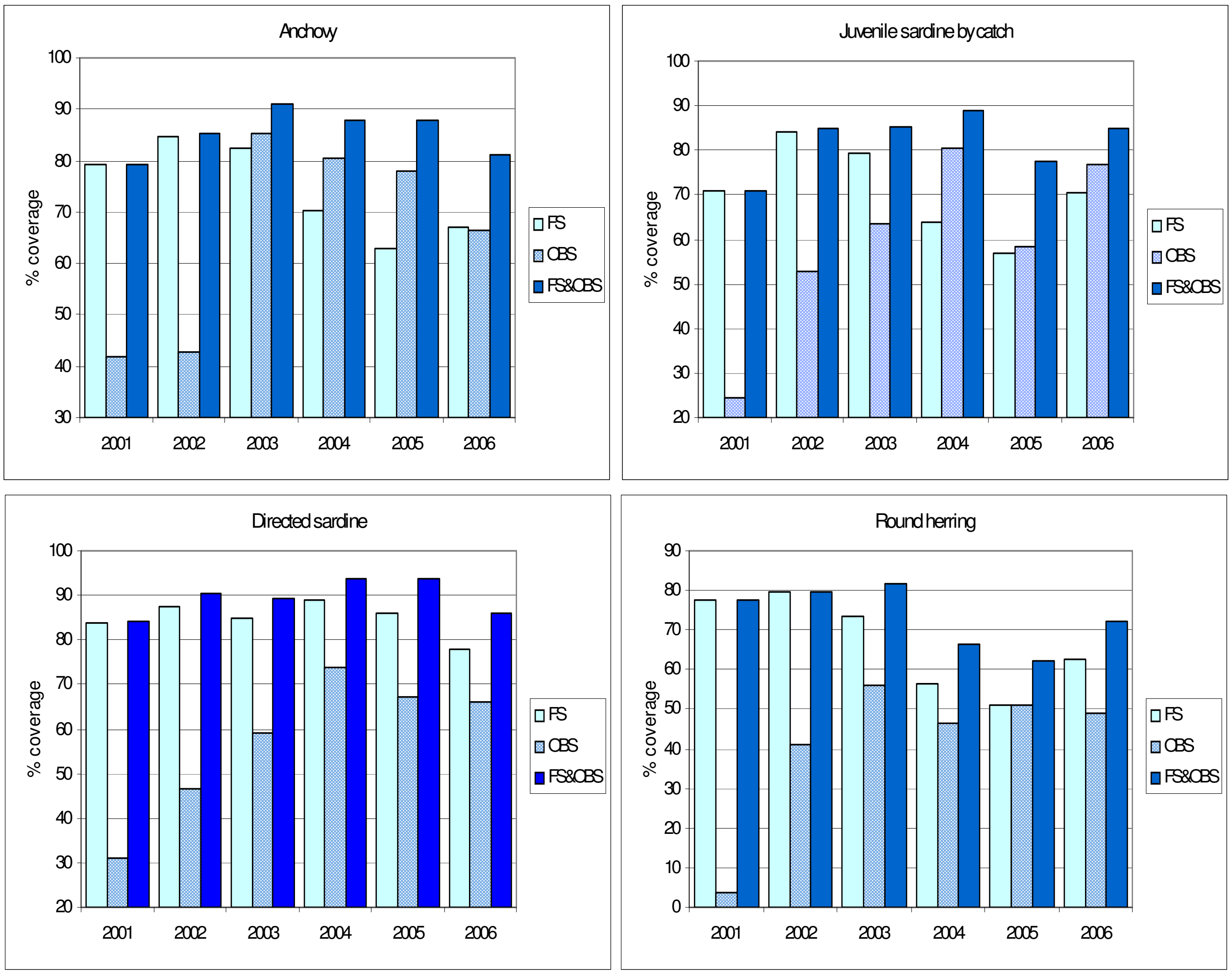

Figure A.1. Coverage obtained on a first level pool-area/week for the field stations (FS), the observers (OBS) and a combination of the two (FS&OBS).

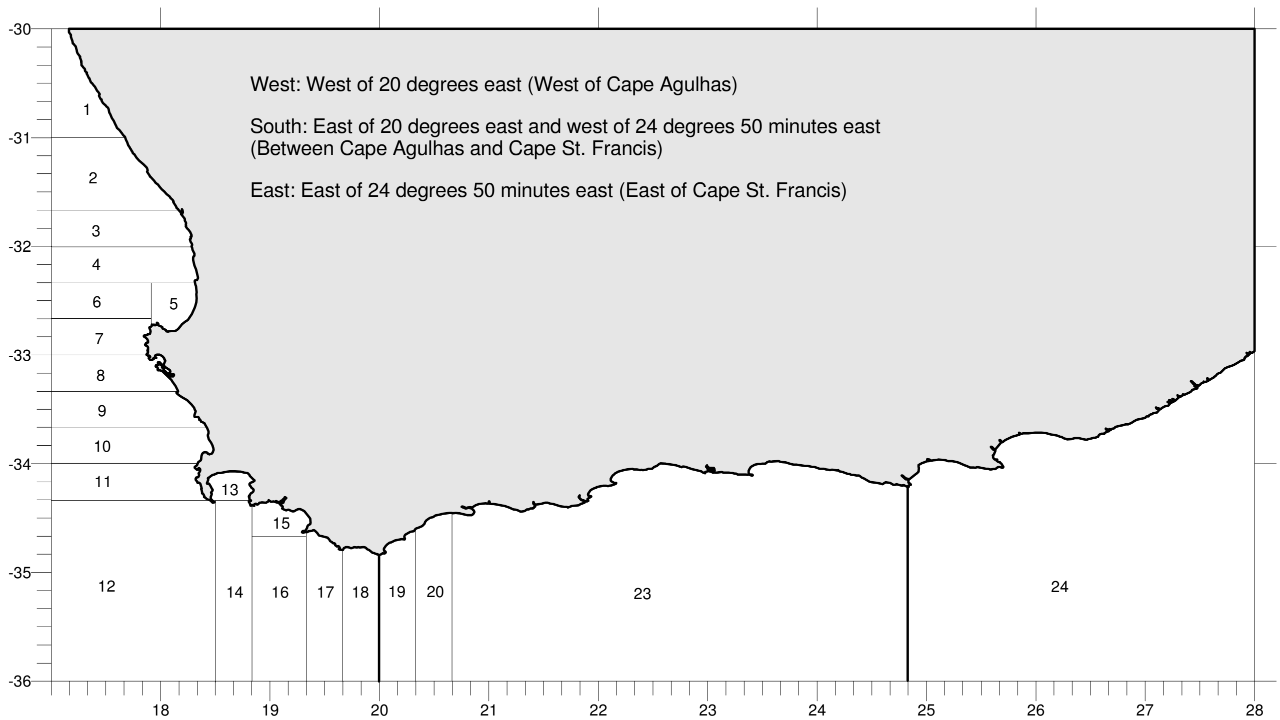

Figure A.2. The pool areas that are used for sample allocation and the three larger areas that are used for the OMP revision.

Appendix B: Sardine Ageing

Routine sardine age determination at MCM was conducted by Michael Kerstan (MK) for the period 1990 – 1999. There was then a four year hiatus until the appointment of Deon Durholtz (DD) in 2004. Sardine age determination activities were subsequently directed at:

1. Comparing DD with MK to ensure data continuity. Otoliths collected during three November surveys conducted during the 1990s (1993, 1994 and 1996) that had been read by both MK and DD were used for this purpose.
2. Generating sardine ALKs from November surveys for the period 2000 – present.

Sardine age determination at MCM currently employs the approach developed by Michael Kerstan during the 1990s. Annual growth zones are identified and their radii measured. A precise age for each fish (± 0.1 years) is computed using a multiple regression approach. The proportion of a year represented by the outermost, incomplete annual growth zone on each otolith is calculated from models describing the radius of complete annual growth zones. Each fish is then assigned to an age group and year class using the winter-to-winter convention appropriate for the Southern Hemisphere (each year class considered to contain fish hatched between 1 July and 30 June of the following year). For example, a fish caught in November displaying a precise age fraction greater than 0.4 will be assigned to an age group 1 year older than the number of complete annual growth zones identified in the otolith.

ALKs generated by DD are listed in Table B.1. Apparent in Table B.1 is that no ALKs are available for the 2000 and 2005 November surveys. An attempt was made to redress these gaps in the series by using ALKs generated from commercial catches landed in November of these years. To test the validity of this approach, the November 2002 survey ALK was compared to a commercial ALK generated from November 2002 landings. Applying these two ALKs to the November 2002 survey raised length frequency (RLF) data resulted in substantial differences, particularly in the relative proportions of 1 year olds in the resulting age structure (Figure B.1). Application of the survey ALK resulted in considerably fewer 1 year olds than two year olds, whereas the commercial ALK generated slightly more 1 year olds than 2 year olds (a more likely scenario). This result indicates that ALKs generated from survey and commercial samples collected during the same period may not be comparable. Comparisons of mean fish lengths at age generated from the two ALKs supported this conclusion. According to the two ALKs, sardine sampled by the commercial fishery during November 2002 were larger than those of the same age sampled during the November 2002 survey, particularly in age groups 1 to 4 (Figure B.2), suggesting that the fishery samples faster growing fish than the survey. Further work is being carried out to establish whether or not this is a "once-off" occurrence or a consistent feature of survey compared to commercial sampling, or an artefact of the otolith reading process.

An additional problem encountered in the sardine age data is that relatively low proportions of 1 year olds are apparent in several of the years for which survey ALKs have been produced. Proportions-at-age displaying this feature were apparent in the 1993, 1994, 1996 and 2002 data, whereas data for 2001, 2003, 2004 and 2006 displayed more realistic proportions-at-age distributions where 1 year olds dominated the population (in terms of numbers). A commercial ALK applied to the survey RLF from 2000 also yielded a low proportion of 1 year olds, whereas commercial ALKs applied to the 2002 and 2005 survey RLFs generated more realistic age distributions. It should be noted that the relatively low proportions of 1 year olds are also a feature of Michael Kerstan's data for 1993, 1994 and 1996. While it is possible that fewer 1 year olds than 2 year olds may occur as a result of variations in recruitment, it is unlikely to occur as frequently as the results described above suggest. Two possible explanations for these results are:

- There is a fundamental problem with the interpretation of age from otolith structure (specifically the identification of the first annulus). A comprehensive validation study will be required to address this possibility.
- Biased sampling (i.e. the November survey under-samples the smaller, younger fish). Note that this does not suggest that acoustic sampling incorporates a substantial bias, but rather it could be argued that trawl samples (the source of the length frequency data) may contain disproportionately fewer younger fish because of the preference of these fish for shallow water where trawling is frequently not practical.

Until this issue is resolved, the approach in the stock assessment will be to assume an age-dependent, multiplicative bias for the proportion-at-age in the November survey. The under-representation of 1 year olds in the survey will therefore be included in the estimated bias factor for proportion-at-age 1.

Although Table B.1 shows that commercial ALKs are available for November 2000, 2002 and 2005 (the years lacking November survey ALKs), these commercial ALKs were not used in the stock assessment because of the apparent discrepancies between survey and commercial ALKs described above. For those years where no survey ALKs are available, model predicted proportions-at-length will be fitted to observed proportions-at-length from survey RLFs.

Table B.1. Sardine age data generated by Deon Durholtz as at September 2007 (values are the number of size-at-age data incorporated into each ALK). Values in bold italics indicate those ALKs that have been spatially disaggregated.

Year	November Survey	November Commercial
1993	587	
1994	620	
1996	335	
2000	No samples or data	736
2001	***526***	To be processed
2002	***570***	526
2003	***145***	To be processed
2004	***322***	To be processed
2005	No samples	241
2006	***442***	Being Processed

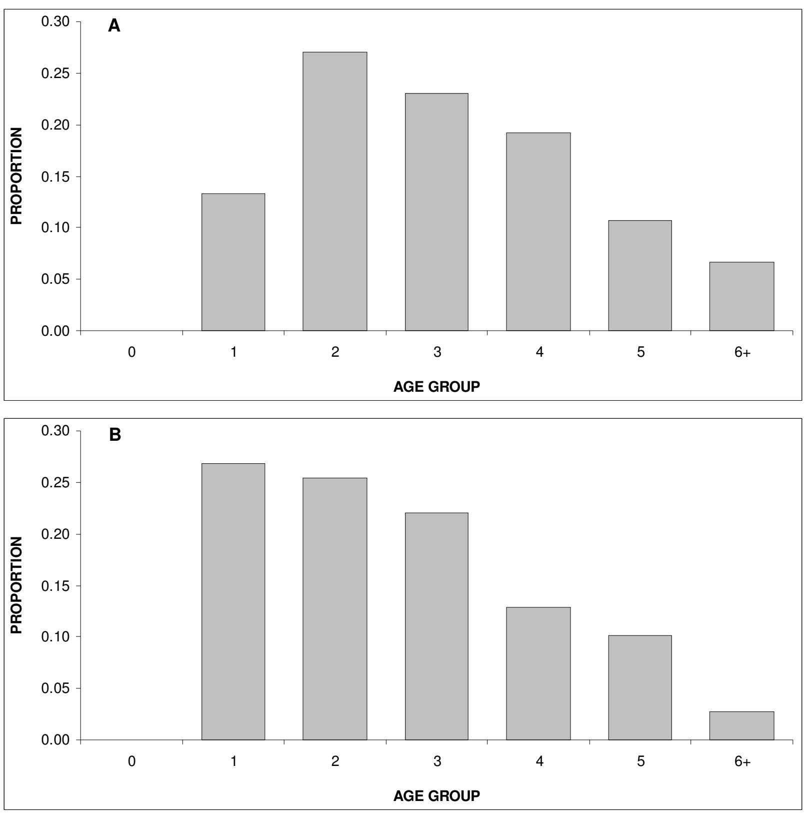

Figure B.1. November 2002 sardine proportions at age obtained from applying (A) the November 2002 survey ALK and (B) the November 2002 commercial ALK to the survey raised length frequency distribution.

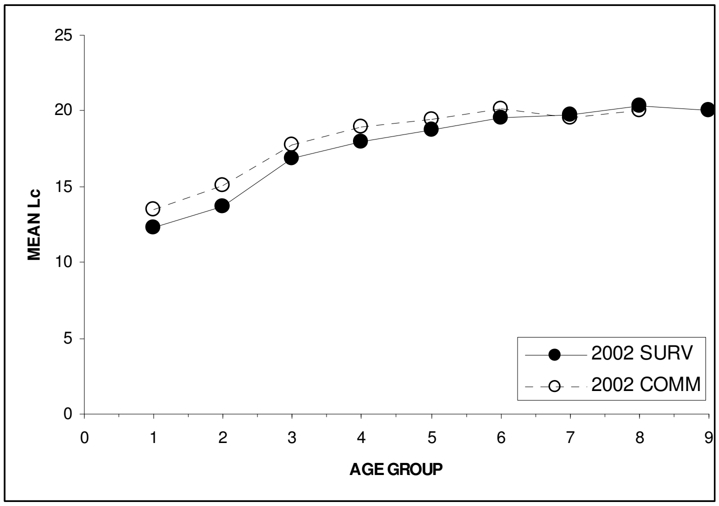

Figure B.2. Comparison of estimates of the mean lengths at age of sardine in November 2002 generated by the survey (solid line, dots) and commercial (dashed line, circles) ALKs.

Appendix C: 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.