A record of the generation of data used in the 2016 sardine and anchovy assessments

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The data to which the South African anchovy and sardine assessments are tuned are not all raw data. Some data have already been subjected to 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 2016. All files referred to below are available from the first author.

Sardine age-length keys for the November surveys derived by Deon Durholtz are available by area (east and west of Cape Agulhas) for 1993, 1994, 1996, 2001 - 2004 and 2006 - 2009. Cynthia Mtengwane has compiled sardine age-length keys by area for the November surveys in 1993, 1994, 1996, 2001, 2003, 2004, 2006 - 2010. Age-length keys for the November surveys from 1984-1999 derived by Michael Kerstan are also available (De Oliveria 2003). Age-length keys for sardine commercial catch for some months each year from 1984 to 1999 were also derived by Michael Kerstan (De Oliveria 2003). Selected monthly age-length keys for sardine commercial catch between 2004 and 2009 have been derived by Cynthia Mtengwane. However, inconsistencies between these age-length keys derived by Kerstan and those from Durholtz and Mtengwane restricted the use of age-length keys from all readers in the assessment. In addition, Smith *et al*. (2011) recommended that these age-length keys not be used to calculate proportions-at-age for use in the assessments due to an inability to detect strong cohorts in the age data (which are known to be present through inference from the survey estimates of abundance). This may be due to problems with ageing and/or problems with the construction of the survey length-frequency data.

Anchovy ALKs for the November surveys from 1992 to 1995 were derived by Prosch (De Oliveria 2003), and by Kerstan for 1990, 1992 to 1995 (unpublished data). These data are not used in the assessment.

Anchovy Commercial Data

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

Monthly length frequencies were constructed for the anchovy landings using the method in Appendix A. Although it is

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possible to split the length frequencies by area from 1987, as the assessment will be run for a single stock in a single area, length frequencies for a single area only are considered. A few 15cm fish were recorded as anchovy landings in September/October 2001, but these were excluded from the assessment as this is most likely a mistake in the reported species. Anchovy catches are mostly inshore and the possibility of landing a 15cm anchovy is small.

In some 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:

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

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 LFs by month and year, i.e. the number of fish in length class *l* in month *m* of year *y*, $N_{y,l,m}$, from 1984 to 2015 are stored in *Anchovy LFs with Cut-Off Lengths.xls*, together with the observed tonnage in each month and year, $ObsT_{y,m}$.

Expected mass by length class and month is calculated as:

$$EM_{y,l,m} = \left\{ 0.008157 - 0.003501 \sqrt{\frac{1}{2\pi 1.9304^2} e^{-\frac{1}{2}\left(\frac{m-8.0616}{1.9304}\right)^2}} \right\} \times l_{mid}^{3.0979} \times N_{y,l,m}$$

where l_{mid} is the mid-point of the length class considered and mass is in grams and length in centimetres. The monthly length-weight relationship is a time-invariant relationship calculated from commercial data collected over 1990-1996 (de Moor and Butterworth 2015). The “raised” length frequency used in the assessment, is then calculated as follows:

$$N'_{y,m,l} = N_{y,m,l} \times \frac{ObsT_{y,m}}{\sum_l EM_{y,l,m}}$$

Annual data used in the assessments are taken over the months November *y*-1 to October *y*, except for 1984 when the sum is from January to October 1984. The monthly catch tonnage is shown in Table 1.

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

Length frequencies were also calculated from 1 May 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 length frequencies 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 number of juveniles landed between 1 May and the day before the commencement of the survey is calculated within the model from these data using selectivity-at-length and length-at-age distributions. These data are available in *Anchovy LFs with Cut-Off Lengths.xls* and the catch tonnage is shown in Table 3.

Sardine Commercial Data

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

Monthly length frequencies were constructed for the sardine landings using the method in Appendix A. From 1987 onwards, these have been split by area (east and west of Cape Agulhas). For the single stock hypothesis, the catch tonnage and length frequencies by month are assumed to be equal to the combined catch tonnage east and west of Cape Agulhas[1].

Between 1987 and 2011, sardine landings were categorized as either directed (>50% sardine mass in landing) or bycatch by the scale monitor. The bycatch was recorded as being either caught with anchovy or round herring, with the allocation determined by the species which formed >50% mass in the landing[2].

From 2012 onwards, the sardine landings have again been categorized as either directed >14cm (>50% sardine mass in landing) or bycatch by the scale monitor. The bycatch is now recorded as either ‘small’ (≤14cm) sardine with directed >14cm, or ‘small’ (≤14cm) or ‘large’ (>14cm). As fish of a similar size tend to shoal together, the assumption is made for this assessment, that the ‘small’ sardine bycatch is primarily bycatch with anchovy and the time series is comparable with the 1987-2011 time series of sardine bycatch with anchovy. Anchovy is seldom[3] landed with adult sardine and/or round herring. The ‘large’ sardine bycatch is assumed to be primarily bycatch with round herring and the time series is assumed comparable with the 1987-2011 time series of bycatch with round herring.

[1] The LFs assigned to sets slightly east of Cape Agulhas would likely have been from Gansbaai landings in a single area scenario, but due to the split in catches at Cape Agulhas, a LF from Mossel Bay area would instead be used. The difference between such single area and two-area LFs is assumed to be minor.
[2] Note that the bycatch recorded in Sybase is exactly according to that reported by the scale monitors and does not necessarily match that recorded by this 50% sample allocation rule. The SPSWG-agreed categorization charts (Anon. 2004) have not been rigorously applied in practice to the data recorded in Sybase.
[3] Occasionally in the area from Cape Point to Cape Agulhas.

The sardine bycatch with anchovy (or 'small' sardine bycatch) is used separately in the assessment to the directed sardine catch and sardine bycatch with round herring. Quarterly data used in the assessments are taken over the months November y-1 to January y , February to April y , May to July y , and August to October y.

Directed sardine and sardine bycatch with round herring

The directed sardine and sardine bycatch with round herring length frequencies by area, month and year, i.e. the number of fish in length class l in area a during month m of year y, $N_{y,l,m,a}$, from 1984 to 2015 are stored in *Sardine Directed and Large Bycatch LFs.xlsx*, together with the observed tonnage in each month and year, $ObsT_{y,m,a}$. For 1984 to 1986 the monthly observed tonnages landed were obtained from length frequency data provided for the assessment in 2004. For calculation purposes, these 1984 to 1986 catch data are all treated as directed and round herring bycatch.

Expected mass by length class and month is calculated as: $EM_{y,l,m} = 0.000011639 \times l_{mid}^{3.03155} \times N_{y,l,m}$

where l_{mid} is the mid-point of the length class considered and mass is in grams and length in millimetres (van der Lingen *et al*. 2006 with correction). The "raised" length frequency used in the assessment, is then calculated as follows:

$$N'_{y,m,l} = N_{y,m,l} \times \frac{ObsT_{y,m}}{\sum_l EM_{y,l,m}}.$$

The monthly catch tonnage is shown by area in Tables 2a and 2b.

Sardine bycatch with anchovy

The sardine bycatch with anchovy length frequencies by area, month and year from 1987 to 2015 are stored in *Sardine Bycatch with Anchovy LFs.xlsx*, together with the observed tonnage in each month and year, $ObsT_{y,m,a}$.

Small amounts of sardine bycatch with anchovy (totalling 20.9t) were recorded east of Cape Agulhas in 1989, 1992, 2007, 2008, 2010, 2011, 2013 and 2014. In the two stock hypothesis these small catches are assumed to be taken west of Cape Agulhas with the remainder of the anchovy bycatch. There was no length frequency recorded with the 0.07t of bycatch east of Cape Agulhas in January 1989. The length frequency of bycatch west of Cape Agulhas in January 1989 was thus assigned to this bycatch.

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

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

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

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

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

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

The cut-off length, $lcut(y,m)$, taken to apply to May and June was set at that used during the recruit survey, which is based on a modal progression analysis (Coetzee and Merkle 2007, given in Table 3). The cut-off length was decreased for months from May back to November, and increased from June through to October. This was done by considering the November survey length frequencies, both back from May to November of the previous year and forward to November of the current year. A faster growth rate was assumed in the earlier months:

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

This resulted in the following monthly cut-off lengths:

	October (y-1) to November (y)														
Month	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Nov-Dec	9.5	9.5	9.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	9.0	8.0	8.0	11.0
Jan-Feb	12.5	12.5	12.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	12.0	11.0	11.0	14.0
Mar-Apr	14.5	14.5	14.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.0	13.0	13.0	16.0
May-Jun	15.5	15.5	15.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	15.0	14.0	14.0	17.0
Jul-Aug	16.5	16.5	16.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	16.0	15.0	15.0	18.0
Sep-Oct	17.0	17.0	16.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	16.5	15.5	15.5	19.0

	October (y-1) to November (y)															
Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Nov-Dec	11.0	6.0	10.0	10.0	8.0	7.5	9.0	6.5	4.5	6.5	7.5	7.5	7.0	6.0	8.0	9.0
Jan-Feb	14.0	9.0	13.0	13.0	11.0	10.5	12.0	9.5	7.5	9.5	10.5	10.5	10.0	9.0	11.0	12.0
Mar-Apr	16.0	11.0	15.0	15.0	13.0	12.5	14.0	11.5	9.5	11.5	12.5	12.5	12.0	11.0	13.0	14.0
May-Jun	17.0	12.0	16.0	16.0	14.0	13.5	15.0	12.5	10.5	12.5	13.5	13.5	13.0	12.0	14.0	15.0
Jul-Aug	18.0	13.0	17.0	17.0	15.0	14.5	16.0	13.5	11.5	13.5	14.5	14.5	14.0	13.0	15.0	16.0
Sep-Oct	19.0	13.5	17.5	17.5	15.5	15.0	16.5	14.0	12.0	14.0	15.0	15.0	14.5	13.5	15.5	16.5

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

The monthly catch tonnages are given in Table 2c.

<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 length frequencies of landings between 1 May and the day before the commencement of the survey (totalled over all catches and bycatches). The cut-off lengths used to calculate the recruit survey biomass, also used to calculate the recruit catch in May and June (see above) were applied.

As for anchovy, inspector data were not available in 1985 and 1986. Daily skippers' estimates of tonnage landed were, however, available for these years. Although the total tonnage landed in May 1985 and June 1986 was estimated by the skippers to be different to that arising from the source data, it was assumed that the proportion of catch taken before the survey compared to the whole month was the same between the skippers' estimates and the source data. Thus RLFs for 1-19 May 1985 and 1-9 June 1986 were calculated as follows:

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

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

These data are stored in *Sardine Catch Before Survey.xlsx* and given in Table 3.

November Survey Data

The time series of total biomass estimates and associated CVs from the acoustic surveys in November each year, corresponding to the standard survey area between Hondeklip Bay and Port Alfred, are given in Table 4 for sardine and anchovy. In addition daily egg production method (DEPM) estimates of anchovy adult biomass between 1984 and 1993 are available and given in Table 4. For assessment purposes we assume this corresponds to spawning biomass.

These survey data are stored in *SurveyData.xls*.

Length frequencies are also available for these standard survey areas and are stored in *WLF for November survey.xlsx*.

Recruit Survey Data

The time series of recruit biomass and associated CVs from the May/June recruit surveys is given in Table 5 for sardine and anchovy. The recruit numbers at the time of the survey were calculated by summing the number of fish smaller than a cut-off length in the weighted length frequency (as per Method 1 of Appendix B). The average recruit weight is calculated by applying a length-weight regression to the weighted length frequency. This mean weight is then adjusted by the difference between the two biomasses (Method 1 of Appendix B). This calculated biomass and average recruit weight were calculated in a separate database, using the uncapped density per interval as input. The two biomass series are not identical due to the different methods of weighting used. A brief description of the two methods is given in Appendix B. Although not ideal, this difference has been narrowed from what has previously been used. This is a matter that needs to be addressed at some stage. In the assessments, the recruit numbers are used together with the CVs on recruit biomass.

These survey data are stored in *SurveyData.xls*.

Parasite Data

The time series of infection prevalence of the "tetracotyle" type digenean endoparasite by length as sampled from November surveys between 2010 and 2015 is available upon request[4] (updated from van der Lingen and Mushanganyisi 2015). This is the proportion of sardine-by-length that are infected with the parasite. The prevalence for western stock sardine is estimated using data from fish collected to the west of Cape Agulhas (20°E), whereas that for southern stock fish is based on samples collected between 22°E (roughly Mossel Bay) and 30°E (roughly Port St Johns) to exclude age-1 individuals in the hypothesized mixing zone (20°-22°E) that may be western stock fish (Dunn et al. 2015). An alternative time series of south coast prevalence based on samples collected between Cape Agulhas and 30°E is used for a model sensitivity test.

Alternative information on the intensity of parasite infection, i.e. numbers of parasite per infected fish, is also available and may be included in later assessments. These data are stored in *Prevalence and Abundance by Length.xlsx*.

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[4] In terms of data confidentiality rules as set out in the DAFF SWG Terms of Reference, raw data have been accorded temporary confidentiality until 1 April 2017 in order to protect first publication rights of the data provider.

Table 1. The monthly anchovy commercial catch tonnage (in thousands of tons).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1984	4.743	16.698	30.497	49.975	69.031	53.193	18.193	0.000	0.000	22.878	7.281	0.000
1985	2.284	11.296	13.005	65.782	74.245	83.354	20.954	0.938	0.784	0.000	0.000	0.000
1986	0.694	13.890	30.537	69.041	47.203	64.662	37.707	28.787	7.068	0.000	0.000	0.000
1987	61.838	114.134	139.674	48.084	14.925	50.851	78.632	67.886	24.357	0.000	0.000	0.000
1988	23.643	108.117	60.589	11.366	50.259	74.417	60.868	70.459	38.843	71.175	3.008	0.000
1989	10.582	62.255	24.864	59.553	83.796	39.623	13.747	0.000	0.000	0.000	0.000	0.000
1990	1.485	0.649	13.561	38.471	37.069	59.514	0.559	0.216	0.035	0.000	0.000	0.000
1991	0.502	2.923	29.246	36.466	22.908	51.769	6.106	1.091	0.025	0.009	0.000	0.000
1992	28.370	11.826	13.471	68.664	58.777	35.221	44.465	57.044	26.366	4.836	0.002	0.002
1993	18.851	20.643	17.703	43.292	14.101	1.196	10.878	67.182	38.890	3.052	0.015	0.065
1994	2.156	19.528	22.211	19.193	42.200	17.431	0.279	30.109	2.830	0.003	0.000	0.000
1995	0.089	0.406	20.440	22.748	13.473	35.621	32.335	39.432	1.873	10.396	1.617	0.000
1996	3.737	5.570	2.779	3.853	10.078	14.578	0.242	0.001	0.002	0.021	0.019	0.000
1997	0.026	0.014	0.000	0.022	1.196	0.758	20.434	10.927	23.355	3.653	0.000	0.000
1998	0.005	0.691	1.132	18.537	23.155	42.516	12.263	3.776	4.407	1.383	0.000	0.000
1999	0.000	0.000	3.548	8.490	19.660	28.584	20.120	33.472	51.708	13.273	1.037	0.000
2000	0.000	0.026	32.352	30.594	41.620	16.153	50.979	55.191	34.363	5.196	0.795	0.022
2001	0.949	8.547	8.285	34.781	34.083	45.297	10.296	30.812	51.150	60.380	2.735	0.195
2002	1.030	6.296	0.179	22.147	6.965	48.724	48.337	35.085	44.024	0.048	0.302	0.308
2003	0.019	0.041	3.524	16.636	23.991	78.245	48.150	16.801	40.602	27.158	3.479	0.232
2004	0.215	1.313	1.447	18.697	39.884	20.901	65.994	23.176	16.266	0.734	1.249	0.219
2005	0.000	2.018	27.919	51.448	56.259	21.245	42.187	27.097	43.257	9.318	1.951	0.028
2006	0.670	2.317	3.459	6.943	7.536	31.404	35.579	20.658	22.852	2.182	0.492	0.093
2007	0.009	0.145	2.252	17.700	58.403	31.053	34.540	37.773	43.707	25.136	0.681	1.691
2008	0.099	2.649	9.632	23.948	34.912	21.353	26.454	59.198	28.840	49.958	8.826	0.779
2009	1.747	11.461	9.782	13.018	18.797	8.903	38.577	35.513	27.714	6.081	2.873	0.000
2010	0.962	6.405	17.317	26.661	15.218	39.444	65.833	40.072	4.962	0.079	0.110	0.000
2011	0.037	3.177	3.136	16.316	24.467	17.060	40.931	14.733	0.016	0.005	0.000	0.000
2012	8.795	19.050	43.246	36.001	57.935	32.047	43.947	21.848	31.944	10.669	1.820	0.000
2013	3.268	0.073	0.025	23.381	17.990	12.717	3.384	3.530	7.995	3.132	3.295	0.012
2014	0.030	26.265	45.775	48.831	43.119	3.936	21.955	19.855	21.961	7.592	1.167	0.012
2015	0.015	4.261	47.193	54.216	68.953	28.559	28.936	4.308	0.224	0.111	0.937	0.018

Table 2a. The monthly sardine commercial catch tonnage (in thousands of tons) landed as directed catch or bycatch with the round herring fishery (1987-2011) or 'large' sardine bycatch (2012-2015), west of Cape Agulhas.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1983											0.072	0.083
1984	1.980	6.802	4.975	6.520	5.114	1.361	0.010	0.000	0.000	0.261	0.131	0.000
1985	3.641	5.715	6.198	4.255	3.274	5.640	1.964	0.011	0.014	0.000	0.000	0.000
1986	1.310	7.319	8.638	3.539	2.714	4.042	2.855	0.162	0.060	0.000	0.000	0.000
1987	3.675	6.322	7.013	5.638	1.851	1.398	0.524	0.218	0.066	0.000	0.000	0.000
1988	1.824	5.312	2.739	5.892	3.904	4.159	2.624	1.323	0.353	0.208	0.912	0.657
1989	1.374	2.549	7.463	4.339	2.639	2.979	1.938	0.774	0.178	0.037	0.176	0.072
1990	3.017	6.014	7.676	6.569	9.338	4.825	3.587	5.148	1.715	0.695	0.344	0.428
1991	2.525	6.128	4.017	6.159	7.451	5.552	5.699	3.993	1.586	1.098	0.124	0.188
1992	0.781	5.147	5.595	2.331	1.967	7.055	2.877	5.347	6.051	1.088	0.292	0.941
1993	4.637	7.868	6.511	4.301	6.452	5.292	1.028	0.990	0.908	1.166	1.306	1.709
1994	1.692	6.264	11.375	7.879	16.378	6.225	6.696	7.297	4.662	5.206	1.224	0.377
1995	2.702	6.036	11.133	6.255	13.839	6.430	5.848	14.945	8.313	12.834	5.350	0.336
1996	2.891	9.022	9.449	7.745	10.287	7.736	5.651	7.590	8.834	10.340	11.219	1.468
1997	1.212	8.445	10.830	12.309	13.970	6.769	13.759	11.877	17.852	7.654	3.164	0.369
1998	2.384	8.419	14.266	6.244	8.491	13.170	13.223	18.716	11.303	14.341	4.447	0.814
1999	2.220	0.225	5.196	5.432	12.910	8.390	13.705	14.801	14.946	6.235	22.781	10.454
2000	0.000	2.458	7.796	10.812	12.949	16.912	11.126	12.413	10.336	19.398	15.934	1.796
2001	2.280	10.687	17.207	13.329	12.713	11.208	5.872	8.497	4.327	25.530	25.739	28.928
2002	0.106	12.317	14.810	26.716	12.163	8.193	8.168	13.312	22.815	25.341	47.652	29.528
2003	3.895	25.308	29.125	21.233	14.750	12.139	6.205	1.838	3.677	22.969	59.235	18.043
2004	8.484	40.646	31.707	17.499	30.774	18.458	15.263	3.619	25.090	18.682	60.672	19.235
2005	0.211	19.855	29.290	18.272	1.009	0.158	1.118	0.130	0.067	4.268	10.148	1.410
2006	1.123	0.907	19.201	5.685	0.593	1.061	0.214	0.304	11.908	19.009	15.628	7.344
2007	3.474	7.503	5.919	5.780	7.019	1.667	3.602	4.877	6.615	3.899	2.850	1.175
2008	0.000	0.767	8.000	7.459	1.455	3.664	1.179	1.195	0.000	7.055	9.012	2.913
2009	0.049	9.052	17.895	12.210	7.563	5.036	3.192	1.911	0.063	0.243	0.161	0.003
2010	0.805	7.418	13.821	9.120	9.261	6.335	6.774	3.008	2.184	0.037	8.920	0.673
2011	0.628	7.671	15.555	7.643	6.199	3.998	11.941	6.616	6.664	2.890	0.126	0.026
2012	5.037	14.860	13.816	10.880	9.071	6.410	1.049	0.850	3.006	4.842	5.715	0.000
2013	1.837	12.260	12.554	11.435	6.904	1.146	0.000	0.000	0.220	2.504	3.797	0.897
2014	5.941	12.185	13.043	9.193	0.946	0.031	0.105	2.890	1.902	4.486	4.534	1.582
2015	1.003	9.553	10.924	4.471	1.087	4.397	1.678	2.311	0.564	9.884	14.485	1.453

Table 2b. The monthly sardine commercial catch tonnage (in thousands of tons) landed as directed catch or bycatch with the round herring fishery (1989-2011) or 'large' sardine bycatch (2012-2015), east of Cape Agulhas. There was no catch east of Cape Agulhas prior to 1989.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1989	0.000	0.000	0.167	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.047	0.000
1990	0.011	0.031	0.153	0.061	0.046	0.031	0.059	0.014	0.000	0.000	0.057	0.016
1991	0.010	0.224	0.114	0.158	0.272	0.074	0.000	0.000	0.000	0.230	0.134	0.164
1992	0.039	0.155	0.544	0.387	0.338	0.201	0.013	0.056	0.126	0.352	0.205	0.051
1993	0.097	0.234	0.378	0.318	0.227	0.196	0.005	0.152	0.161	0.119	0.142	0.270
1994	0.011	0.633	0.270	0.315	0.561	0.607	0.534	0.481	0.144	0.395	0.072	0.345
1995	0.365	0.743	0.605	0.062	0.481	0.159	0.309	0.135	0.257	0.837	0.594	0.395
1996	0.064	0.533	0.456	0.400	1.073	0.731	0.625	0.539	0.672	0.398	1.136	0.915
1997	0.093	0.290	0.741	0.362	0.640	0.369	1.234	0.134	0.105	0.298	0.000	0.000
1998	0.012	0.000	0.536	0.612	0.972	1.156	0.554	0.069	0.168	0.016	0.100	0.000
1999	0.708	0.061	0.413	0.692	0.817	0.943	0.255	0.408	0.457	0.709	1.006	0.623
2000	0.000	0.271	0.541	0.754	1.444	1.133	0.138	0.688	0.357	0.172	0.505	0.044

Table 2b (continued).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Sep	Aug	Oct	Nov	Dec
2001	0.135	0.304	0.537	0.497	0.657	0.992	1.253	1.798	2.178	1.481	1.152	0.296
2002	0.000	0.885	0.671	0.678	2.493	2.880	4.275	4.873	3.314	3.051	2.712	1.419
2003	0.586	2.005	2.172	2.669	6.255	7.391	9.603	6.849	9.180	6.531	6.066	1.693
2004	0.534	1.660	2.543	4.306	7.630	10.285	10.250	15.521	9.307	9.738	4.287	1.393
2005	0.468	4.889	5.332	10.422	19.516	24.672	25.615	18.544	18.181	9.052	16.047	2.232
2006	0.947	6.454	10.630	12.736	28.192	25.894	17.695	8.775	3.450	3.823	3.469	3.114
2007	0.441	6.538	10.762	12.977	16.470	15.113	7.227	4.603	3.252	0.160	2.033	1.608
2008	0.344	2.088	3.175	13.837	8.529	3.685	7.192	2.254	0.236	1.055	1.055	0.567
2009	0.671	2.725	4.318	6.829	7.009	4.400	3.328	0.374	0.932	1.267	0.876	1.412
2010	0.814	2.443	3.156	2.836	3.460	3.256	3.030	3.262	2.607	0.292	0.032	0.905
2011	0.419	3.115	3.551	2.018	4.591	3.571	3.719	4.794	2.347	0.905	1.330	0.434
2012	1.048	2.582	4.278	4.027	5.513	4.092	1.958	0.863	0.807	0.215	0.312	0.437
2013	0.476	1.900	2.732	4.032	4.811	6.063	5.114	5.657	1.741	2.457	0.015	0.210
2014	0.088	0.669	3.832	3.782	6.940	6.277	9.034	1.683	1.696	0.439	0.000	0.000
2015	0.000	0.003	0.347	3.989	7.164	3.849	3.333	2.274	0.169	0.000	0.000	0.000

Table 2c. The monthly sardine commercial catch tonnage (in thousands of tons) landed as bycatch with the anchovy fishery (1987-2011) or 'small' sardine bycatch (2012-2015), west of Cape Agulhas. These data include the small amounts of sardine landed east of Cape Agulhas as described in the text. Note that the sardine bycatch with anchovy LFs have been recorded according to the sample allocation rule.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987	0.018	0.187	0.280	1.415	0.329	1.462	1.521	1.407	0.206	0.000	0.000	0.000
1988	0.032	0.291	0.115	0.058	1.216	2.391	0.520	0.724	0.154	0.689	0.235	0.000
1989	0.135	2.144	0.970	1.783	2.988	1.576	0.399	0.000	0.000	0.000	0.000	0.000
1990	0.019	0.193	0.477	1.012	2.073	3.797	0.012	0.000	0.000	0.000	0.000	0.000
1991	0.010	0.074	1.473	2.778	0.518	2.174	0.029	0.005	0.000	0.000	0.000	0.000
1992	0.142	0.501	0.465	2.456	1.668	2.565	2.281	2.767	0.277	0.008	0.000	0.000
1993	0.070	0.179	0.500	1.397	1.376	0.204	0.619	1.552	0.559	0.163	0.000	0.000
1994	0.286	1.972	1.683	1.359	4.447	1.936	0.039	3.460	0.032	0.000	0.000	0.000
1995	0.046	0.026	1.024	0.735	1.890	4.306	5.076	6.133	0.447	1.970	0.535	0.000
1996	1.015	1.931	0.689	0.624	1.846	1.960	0.007	0.000	0.000	0.004	0.000	0.000
1997	0.073	0.006	0.005	0.002	0.243	0.267	1.469	0.735	3.226	0.863	0.000	0.000
1998	0.028	1.118	0.143	1.762	3.674	4.492	0.960	0.183	0.697	0.262	0.000	0.000
1999	0.000	0.000	0.318	0.381	1.364	2.288	0.490	0.730	1.393	0.482	0.089	0.000
2000	0.000	0.000	1.403	1.798	1.897	1.146	0.611	0.317	0.030	0.021	0.000	0.000
2001	0.001	0.244	0.243	0.981	2.258	2.623	1.098	3.431	1.291	1.689	0.046	0.028
2002	0.040	0.185	0.000	0.353	0.402	1.836	1.297	5.681	2.709	0.000	0.000	0.009
2003	0.000	0.000	0.182	1.845	2.137	4.290	1.130	0.118	0.280	0.462	0.130	0.000
2004	0.000	0.017	0.002	0.956	3.298	0.474	0.706	0.604	0.186	0.000	0.003	0.000
2005	0.000	0.072	0.995	1.279	1.507	0.384	0.393	0.260	0.520	0.266	0.131	0.000
2006	0.000	0.000	0.142	0.352	0.698	2.303	2.764	0.980	1.818	0.065	0.006	0.000
2007	0.000	0.003	0.061	0.724	1.972	0.365	0.202	0.291	0.123	0.191	0.000	0.004
2008	0.000	0.042	0.156	0.503	1.461	0.756	0.289	0.490	0.137	0.090	0.273	0.004
2009	0.000	0.066	0.181	0.776	0.382	0.327	0.360	0.564	0.059	0.081	0.010	0.000
2010	0.088	0.187	1.856	2.124	2.512	5.356	4.166	1.598	0.036	0.046	0.015	0.000
2011	0.008	0.066	0.162	1.523	3.372	1.257	3.787	1.215	0.000	0.000	0.000	0.000
2012	0.553	0.913	0.600	0.948	2.856	0.653	0.253	0.190	0.216	0.495	0.017	0.000
2013	0.053	0.000	0.000	0.625	2.010	0.633	0.006	0.000	0.005	0.000	0.055	0.000
2014	0.000	1.071	1.247	1.957	1.550	0.015	0.026	0.112	0.046	0.009	0.000	0.000
2015	0.000	1.654	4.180	2.326	4.628	0.414	0.045	0.007	0.003	0.000	0.001	0.000

Table 3. The date of the commencement of the annual recruit survey; juvenile anchovy catch (in thousand tons) between 1 May and the day before the survey commenced; the cut-off lengths used to estimate juvenile anchovy and sardine from the recruit surveys; and juvenile sardine catch (in billions) from 1 May to the day before the annual recruit survey.

Year	Date of commence-ment of survey	Time of the recruit survey after 1 May	Anchovy catch before the survey ('000t)	Cut-off length (cm) for anchovy juveniles in the survey	Cut-off length (cm) for sardine juveniles in the survey	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	74.245	<10.5	<15.5	0.1437	0.0000
1986	10-Jun	1.300	111.865	<10.5	<15.5	0.2924	0.0000
1987	20-Jul	2.613	113.899	<11.0	<15.0	0.1950	0.0000
1988	27-Jun[5]	1.867	99.855	<11.5	<16.0	0.2940	0.0000
1989	08-Jun[6]	1.233	94.984	<10.5	<16.0	0.3420	0.0000
1990	22-Jun	1.700	93.015	<10.5	<16.0	0.7215	0.0000
1991	07-May	0.194	9.635	<10.5	<16.0	0.0084	0.0000
1992	13-May	0.387	7.701	<10.5	<16.0	0.0290	0.0000
1993	21-May	0.645	8.276	<10.5	<16.0	0.0423	0.0001
1994	05-May	0.129	7.111	<9.5	<16.0	0.0671	0.0000
1995	10-Jun	1.300	25.721	<10.5	<16.0	0.5299	0.0000
1996	05-Jun	1.133	15.504	<10.5	<15.0	0.3304	0.0000
1997	17-May	0.516	1.161	<10.0	<14.0	0.0348	0.0000
1998	20-May	0.613	18.676	<10.5	<14.0	0.4215	0.0000
1999	10-May	0.290	1.229	<10.0	<17.0	0.0223	0.0001
2000	15-May	0.452	15.712	<9.5	<17.0	0.1075	0.0001
2001	05-May	0.129	0.662	<9.0	<12.0	0.0003	0.0000
2002	05-May	0.129	2.158	<11.0	<16.0	0.0325	0.0000
2003	14-May	0.419	1.693	<10.0	<16.0	0.0732	0.0007
2004	08-May	0.226	4.978	<11.0	<14.0	0.0303	0.0000
2005	13-May	0.387	27.630	<9.5	<13.5	0.0887	0.0001
2006	19-May	0.581	2.922	<9.5	<15.0	0.0334	0.0001
2007	18 May	0.548	22.643	<9.5	<12.5	0.0596	0.0000
2008	21 May	0.645	21.810	<9.5	<10.5	0.0974	0.0000
2009	15 May	0.452	12.975	<10.5	<12.5	0.0256	0.0000
2010	27 May	0.839	10.623	<11.0	<13.5	0.2269	0.0009
2011	27 May	0.839	23.993	<11.0	<13.5	0.3941	0.0007
2012	16 June	1.500	84.055	<9.5	<13.0	0.2232	0.0000
2013	23 May	0.710	12.596	<10.0	<12.0	0.1282	0.0000
2014	10 May	0.290	9.099	<9.0	<14.0	0.0001	0.0000
2015	22 May	0.677	11.457	<10.5	<15.0	0.2506	0.0000

[5] The first station was on 27th June 1988, although the first acoustic interval was only logged after midnight, i.e. on 28th June 1988.
[6] 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 4. Sardine and anchovy total biomass (in tons) as far as Port Alfred and associated CV from the November acoustic survey and anchovy spawner 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 Biomass (t)	CV	Sardine Biomass (t)	CV	Sardine Biomass (t)	CV	Sardine Biomass (t)	CV	Anchovy Spawner Biomass (t)	CV
1984	1553813	0.282	48378	1.118	48009	1.127	369	0.644	1100000	0.45
1985	1366294	0.211	45013	0.509	25457	0.680	19556	0.767	616000	0.4
1986	2568625	0.172	299797	0.848	238230	1.054	61566	0.672	2001000	0.35
1987	2108771	0.157	111285	0.630	94165	0.734	17120	0.693	1606000	0.3
1988	1607060	0.222	134362	0.957	128043	1.005	6319	0.525	1679000	0.35
1989	751529	0.167	256655	0.274	198328	0.334	58327	0.397	421000	0.35
1990	651711	0.183	289876	0.352	248855	0.382	41020	0.905	723000	0.58
1991	2327834	0.159	597858	0.395	517180	0.444	80678	0.675	2913000	0.35
1992	2088025	0.161	494157	0.658	247756	0.560	246401	1.191	3600000	0.31
1993	916359	0.209	560019	0.427	480822	0.488	79198	0.603	770000	0.34
1994	617276	0.159	518354	0.370	389730	0.432	128624	0.709		
1995	601271	0.217	843944	0.713	363542	0.302	480402	1.229		
1996	162048	0.410	529456	0.471	257763	0.352	271693	0.849		
1997	1482633	0.267	1224632	0.329	964835	0.322	259797	0.982		
1998	1229132	0.217	1607328	0.251	1082547	0.341	524781	0.305		
1999	2052156	0.156	1635410	0.212	708029	0.324	927381	0.280		
2000	4653779	0.125	2292380	0.500	726230	0.633	1566150	0.670		
2001	6720287	0.107	2309600	0.142	669617	0.313	1639983	0.154		
2002	3867649	0.154	4206250	0.227	1184713	0.247	3021538	0.300		
2003	3563232	0.236	3564171	0.197	1343118	0.300	2221053	0.258		
2004	2044615	0.131	2615715	0.334	292522	0.437	2323193	0.372		
2005	3077001	0.144	1048991	0.300	75604	0.524	973386	0.321		
2006	2106273	0.136	712557	0.346	177890	0.414	534667	0.441		
2007	2505655	0.157	252199	0.351	53138	0.541	199061	0.421		
2008	3598790	0.120	384080	0.422	211871	0.528	172209	0.682		
2009	3792547	0.136	501575	0.271	262175	0.285	239400	0.474		
2010	2077414	0.144	508392	0.235	309465	0.328	198927	0.314		

Table 4 (continued).

	Acoustic								DEPM	
Area	Hondeklip Bay to Port Alfred				Hondeklip Bay to Cape Agulhas		Cape Agulhas to Port Alfred		Full Area	
Year	Anchovy Biomass (t)	CV	Sardine Biomass (t)	CV	Sardine Biomass (t)	CV	Sardine Biomass (t)	CV	Anchovy Spawner Biomass (t)	CV
2011	754124	0.204	1037060	0.235	182825	0.187	854235	0.283		
2012	3187964	0.116	345054	0.345	186109	0.517	158945	0.440		
2013	3819666	0.102	611763	0.346	467613	0.432	144150	0.443		
2014	2970760	0.137	444500	0.291	195786	0.476	248715	0.361		
2015	1944258	0.157	363230	0.297	98467	0.312	264763	0.391		

Table 5. 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. Blank cells correspond to years/areas for which data are not available.

	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	Num-bers*	Biomass (Method 1 of App B)	Biomass (Method 2 of App B)	CV*	Mean Weight	Num-bers*	Biomass (Method 1 of App B)	Biomass (Method 2 of App B)#	CV*	Mean Weight	Num-bers*
1985[7]	348.547	344.245	0.276	4.176	83.454	37.424	37.636	0.649	10.420	3.592					
1986[8]	632.317	632.181	0.184	4.433	142.640	45.336	43.404	0.609	12.284	3.691					
1987[9]	692.912	704.070	0.167	5.438	127.424	90.525	89.842	0.554	12.266	7.380					
1988[7]	574.870	574.773	0.164	4.352	132.106	4.461	4.742	0.462	10.134	0.440					
1989[7]	165.329	166.007	0.205	4.874	33.920	47.394	46.415	0.426	22.176	2.137					
1990[7]	173.607	173.640	0.225	3.316	52.362	27.317	28.284	1.079	10.920	2.502					
1991	519.845	521.418	0.151	4.577	113.584	22.864	22.769	0.269	11.939	1.915					
1992	427.933	438.584	0.161	4.568	93.681	68.554	69.608	0.363	12.170	5.633					
1993	448.144	445.794	0.266	3.895	115.058	108.133	109.591	0.367	7.096	15.238					
1994	129.890	135.023	0.184	4.251	30.554	58.091	57.208	0.324	21.886	2.654	19.496	18.227	0.555	28.028	0.696

* Data to which the assessments are tuned.

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

[7] The 1985 survey area included a single stratum from east of Danger Point to Mossel Bay. This full area is included in the survey estimate and thus the estimate is higher than that which would correspond to a survey area west of Cape Infanta only. It is thus not strictly comparable with the rest of the time series, but given the low survey estimate, it is considered acceptable for this assessment.

[8] Biomass and numbers west of Cape Infanta were estimated by taking that observed up to east of Danger Point and increasing by 0.0239 for anchovy and 0.038 for sardine. These increase factors are the average 1991-5,1998,1999 ratios of numbers of recruits surveyed between Cape Agulhas-Cape Infanta to those surveyed west of Cape Agulhas, and thus the resultant values will be underestimated of that present for the full area west of Cape Agulhas. The CV was also adjusted according to the method of de Moor and Butterworth (2011), but no changes occur to the first three decimal places.

[9] Biomass and numbers west of Cape Infanta were estimated by taking that observed up to Cape Agulhas and increasing by 0.0239 for anchovy and 0.038 for sardine. These increase factors are the average 1991-5,1998,1999 ratios of numbers of recruits surveyed between Cape Agulhas-Cape Infanta to those surveyed west of Cape Agulhas. The CV was also adjusted according to the method of de Moor and Butterworth (2011), but no changes occur to the first three decimal places.

1995	391.859	391.749	0.179	3.548	110.439	195.250	194.506	0.378	7.691	25.388	4.528	3.388	0.467	19.141	0.237
1996	72.199	72.077	0.220	2.802	25.771	52.678	48.154	0.453	16.441	3.204	7.811	7.547	0.480	19.113	0.409
1997	402.596	402.624	0.186	4.463	90.210	340.160	342.363	0.402	9.229	36.856					

Table 5 (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*
1998	451.514	451.211	0.150	3.307	136.518	124.952	129.664	0.360	11.660	10.716	5.238	5.207	0.540	19.642	0.267
1999	813.098	812.242	0.158	4.081	199.228	220.589	219.249	0.376	21.255	10.378	58.613	53.909	0.519	45.419	1.290
2000	2477.589	2474.927	0.168	3.966	624.675	265.489	264.452	0.390	13.273	20.002	168.591	165.955	0.495	31.870	5.290
2001	2027.740	1946.112	0.135	3.233	627.200	553.538	559.079	0.287	9.216	60.065	0.005	0.003	0.713	9.932	0.0005
2002	1541.803	1543.397	0.115	2.963	520.413	610.344	595.913	0.182	12.417	49.153	41.495	37.613	0.958	31.103	1.334
2003	1391.468	1396.638	0.189	3.234	430.308	508.911	501.624	0.209	13.963	36.448	19.948	19.553	0.553	43.572	0.458
2004	1060.548	1058.653	0.219	4.445	238.569	25.871	26.003	0.342	6.326	4.089	4.187	4.477	0.732	7.191	0.582
2005	535.958	550.235	0.273	3.029	176.917	16.736	16.896	0.343	5.823	2.874	20.658	21.754	0.460	19.357	1.067
2006	259.194	263.889	0.174	2.207	117.465	49.926	50.067	0.381	5.220	9.564	62.564	62.881	0.649	17.721	3.530
2007	1499.082	1505.898	0.184	2.959	506.703	29.689	32.777	0.343	10.110	2.937	17.987	19.218	0.892	13.505	1.332
2008	1432.841	1426.705	0.202	2.544	563.156	20.555	19.610	0.266	5.337	3.852					
2009	1307.613	1306.045	0.189	3.598	363.387	57.740	55.111	0.776	6.271	9.207	64.360	63.474	1.018	17.762	3.623
2010	1667.695	1667.994	0.267	4.351	383.328	477.437	479.609	0.473	13.423	35.569	6.984	6.781	0.924	20.076	0.348
2011 [10]	288.405	288.417	0.283	2.700	104.166	55.294	55.353	0.475	9.803	5.470					
2012	963.758	971.350	0.137	4.607	209.205	87.815	87.375	0.316	11.672	7.524					
2013	1168.855	1164.278	0.182	3.311	352.987	104.253	102.169	0.416	8.599	12.124	0.576	0.587	0.951	18.417	0.031
2014	551.800	544.509	0.340	3.075	179.472	24.171	25.073	0.622	12.179	1.985	28.866	28.186	0.677	23.181	1.245
2015	1154.211	1151.838	0.147	4.394	262.698	241.822	262.752	0.388	26.180	9.237	49.232	49.944	0.579	29.826	1.651

* Data to which the assessments are tuned.

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

10 Biomass and numbers west of Cape Infanta were estimated by taking that observed up to Cape Agulhas and increasing by 0.03 (de Moor and Butterworth 2011).

Appendix A: Pelagic sample allocation

The sample allocation method is the process whereby a length frequency (LF) 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 DAFF network. Length frequency data from the observer program (2001 to 2011) and Industry canneries (2011 onwards) are included in the calculation. 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 LFs for anchovy (*Engraulis encrasicolus)* and sardine (*Sardinops sagax)* though LFs 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 per set and a pelagic 10′ by 10′ block position. Every landing is sampled for its species composition and weighed. The fisheries inspectors started the task of scale monitor and hence the catch sheet is referred to as the inspector’s form. Normally this function is contracted to a private entity. Skipper data are available on Sybase from 1984 onwards but inspector data were obtained only from 1987. DAFF field station personnel collect data sheets and enter the information on Sybase.
- Field station samples: DAFF field station personnel collect random samples at the major pelagic fishing harbors for species composition and length frequency (Capricorn Fishing Monitoring 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 was terminated in 2011. 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.

- Industry cannery samples: As part of the quality process at the canneries, fish are also measured and weighed according to DAFF field station specification.

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>DAFF 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 validation 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. From 2015 the entering of data into Access was stopped because this data in now obtained from Industry and used to verify the catches.
- 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

RLFdata.accdb (where the LFs are generated)
This program has links to the following data sets that is required for the computation.

1) Cannery data.accdb (sardine length frequency)
2) RSAP reference.accdb (data set with vessel detail and pool positions)
3) Capfish.accdb (if data from 2001 to 2011 is included)
4) Pel Catch (skipper data sets)

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 from 1999 onwards 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 length frequency is estimated using the 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 length frequencies 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, the border between area 23 and 24 was shifted slightly west to 24 degrees east (Tsitsikama), although this made little difference in practice since catches between 23 and 24 were small.

Although the LFs 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 LF 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.
- From 2012 the cannery length frequencies are included.

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 LF 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 LF average was used, but it was felt that it is better to allocate the LF from the adjacent month. The LFs 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

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 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.

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. In earlier years field stations were well manned and more samples were taken than presently. The Observer program was introduced in 2000 and this improved sampling and as a result field station sampling was reduced. However, when the program was terminated in 2011 the field station coverage was not adjusted to earlier levels. This poor coverage can be seen see as the low values on the graph in Figure A.1. The fisheries cannery data (used since 2012) is necessary to maintain directed sardine sampling levels.

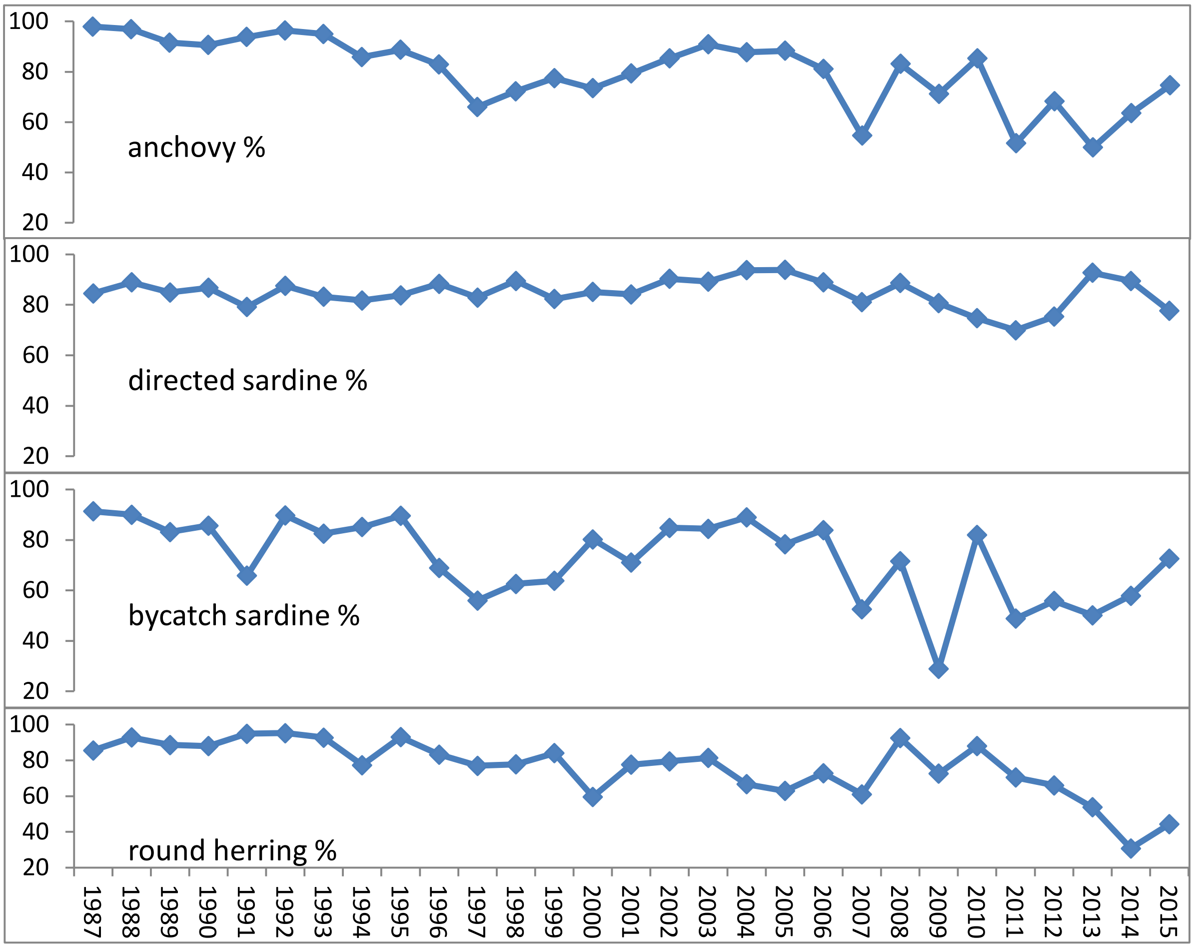

Figure A.1. Sampling coverage obtained on a first level pool-area/week.

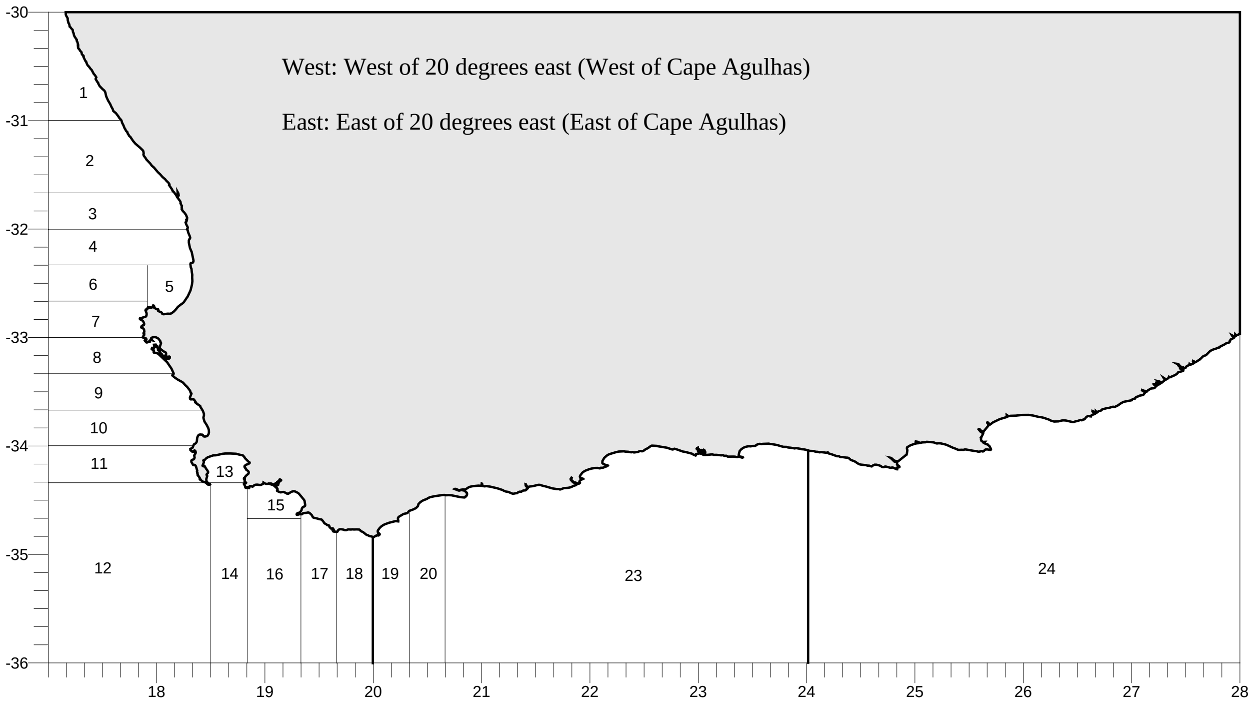

Figure A.2. The pool areas that are used for sample allocation.

Appendix B: Methods Used to Calculate Recruit Biomass

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

Method 1

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

1) The acoustic biomass per stratum (of adults and recruits) is calculated using the Jolly and Hampton method (i.e., each interval is weighted by interval length and a mean density per transect is calculated. Each transect is again weighted by its length to get a mean density per stratum).

2) Each acoustic interval has been linked to a particular grid reference (trawl sample) which was used to scale the acoustic energy to density. The trawl sample has a length frequency (LF) and associated length frequency mass (LFMASS). This LF and LFMASS include both adults and recruits as it is impossible at this stage (at sea) to know what the cut-off length for a recruit is. The LFMASS is the total weight of the LF sample (the combined weight of all fish of a particular species measured for the LF distribution).

3) For each interval, the acoustic density is multiplied by the interval length. This weighted interval density is then summed over all intervals for each grid reference, per stratum and per species to give an acoustic weighting to each grid reference, $W_{GR}(grid,stratum,species)$.

4) The weighted grid reference is then summed over all grid references for each stratum and species to give a weighted grid reference per stratum for each species, $W_{GR}(stratum,species)$.

5) For each length class of each grid reference, calculate a Trawl WF (trawl weighting factor) $=W_{GR}$(grid,stratum,species)/LFMASS. This converts the acoustic weighting (in terms of mass) into a factor in terms of numbers.

6) The length frequency (LF) is then weighted by this Trawl WF and summed for each length class to give a weighting to each length class (Lgroup) for each stratum for each species sum(number*trawl WF), *WLF(Lgroup,stratum,species)*.

7) *WLF(Lgroup,stratum,species)* is then scaled to the biomass of the stratum: $BLF(Lgroup,stratum,species)=[WLF(Lgroup,stratum,species)]*[BIOMASS(stratum,species)]/[\Sigma W_{GR}(stratum,species)]$.

8) BLF is then summed across all strata for each species to give a final length frequency per species for the survey (this is done separately up to Cape Infanta and for the whole survey).

9) For each species an age/length matrix is then generated using a cut-off length for recruits.

10) The proportion in each length class is multiplied by BLF to get the total number of 0-year olds (recruits) and the total number of 1-year olds (adults). This is again done separately as far as Cape Infanta and for the whole survey. The number of fish in each length class is then multiplied by a length weight regression to get an

estimated weight (in grams) for each length class, where $w = 0.00924 \times Lgroup^{3.046}$ for anchovy and $w = 0.0096 \times Lgroup^{3.075}$ for sardine.

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

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

Method 2

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

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

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

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

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

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

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

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

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