# Update regarding Potential Directed Sardine TAC for 2007

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## Introduction

The sardine spawner biomass observed in November 2005 indicated a decrease in sardine abundance from the record levels experienced over the preceding five years. Sardine recruitment was poor for 2004 and 2005, but the estimate from the most recent recruitment survey in May 2006 was closer to the long term average. In line with work carried out over the past two years (Cunningham and Butterworth 2004b, 2004c, 2005), the Marine and Coastal Management Pelagic Working Group has again requested an update regarding the potential future directed sardine TAC for 2007, given data collected prior to and during the May 2006 recruit survey.

As in Cunningham and Butterworth (2005), a coarse update of the most recent sardine assessment was carried out, now taking into account data that have become available since that assessment and which include surveys from November 2003 to May 2006.

## Methods

The population dynamics model used for the South African sardine resource is unchanged from that detailed in Appendix A of Cunningham and Butterworth (2004a). The data and biological parameters used in the sardine assessment model are listed in Appendix B of Cunningham and Butterworth (2004a), with the subsequent data described below. AD Model Builder (Otter Research Ltd. 2000) was used to fit the model and find the posterior mode. No posterior probability distributions could be estimated in the time available for this work.

A distribution of the predicted sardine biomass in 2006 was generated by adding contributions from two sources. A likelihood profile of the predicted 2+ biomass in November 2006 was output from AD Model Builder. Because of the importance of the contribution to the overall biomass from this year's recruits, and the need for computations possibly more accurate than provided by the likelihood profile approach, a distribution of the predicted biomass of 1-year-olds in November 2006 was generated separately and more directly. A distribution of recruitment in May 2006 was generated from the May 2006 recruitment survey result and associated CV, together with a distribution for the estimated bias for these surveys; these were combined to obtain a model-predicted distribution of recruitment in May 2006, which was

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back-projected to recruitment in November 2005, and then forward projected to November 2006 by applying the equations used in standard assessments. The survey sampling CV used to generate possible November survey results from the resultant distribution for the underlying abundance was set at 0.24, the average CV from the past 5 years.

Due to the influence of the hockey-stick stock-recruitment function on the model predicted recruitment in November 2003 to 2005 (observed in May 2004 to 2006), a sensitivity test was also run assuming a much wider prior distribution on the recruitment residuals in 2003 to 2005, i.e.

$$\varepsilon_y^S \sim \begin{cases} N\left(0, 0.4^2 + \left(\lambda_0^S\right)^2\right) & y = 1979,\ldots,2002 \\ N\left(0, 1^2 + \left(\lambda_0^S\right)^2\right) & y = 2003,\ldots,2005 \end{cases}.$$

This has the effect of placing much greater weight (in relative terms) on the results from the recruitment surveys of the last three years.

The following data were used in this updated assessment.

1) Sardine spawner biomass observed during the November 2004 and 2005 surveys:
$B^S_{2004,Nov}$ = 2 617 125.33 tonnes, with a CV of 0.334; $B^S_{2005,Nov}$ = 962 229.37 tonnes, with a CV of 0.322.
2) Sardine recruitment observed during the May 2004, 2005 and 2006 recruit surveys: $N^S_{2004,rec} = 8.791$ billion, with a CV of 0.270; $N^S_{2005,rec} = 3.569$ billion, with a CV of 0.280; and $N^S_{2006,rec} = 18.520$ billion, with a CV of 0.368.
3) Time between 1 May and the start of the 2004, 2005 and 2006 recruit surveys: $t^S_{2004} = 0.226$ months (7 days); $t^S_{2005} = 0.387$ months (12 days); and $t^S_{2006} = 0.613$ months (19 days).
4) Sardine recruit catch from 1 November to day before commencement of the recruit survey in the following year for 2003/4, 2004/5 and 2005/6: $C^S_{2004,0bs} = 0.629$ billion, with an associated mean weight of $w^S_{2004,0cbs} = 28.29$ g; $C^S_{2005,0bs}$ = 0.58 billion, with an associated mean weight of $w^S_{2005,0cbs} = 22.33$ g; $C^S_{2006,0bs} = 0.14$ billion, with an associated mean weight of $w^S_{2006,0cbs} = 16.61$ g. This catch is estimated assuming all sardine < 15.5cm are recruits and the mean weight is calculated by weighting data disaggregated by area and month.
5) Sardine catch-at-ages and catch weights-at-ages 0 to 4 from November 2003 to October 2006 (listed in Table 1) are based on the same average ALK (Age-Length Key) calculated from the 1997 to 1999 ALKs used to calculate the 2000 to 2003 catch-at-age in Cunningham and Butterworth (2004a). The 2003 and 2004 data remain unchanged from Cunningham and Butterworth (2005), while the RLFs (Raised Length Frequencies) for 2005 have been updated.
6) Sardine catch-at-ages and catch weights-at-ages 0 to 4 from November 2005 to June 2006 were calculated based on the same average ALK calculated from the 1997 to 1999 ALKs. The catch-

at-age for these 8 months corresponded to a catch biomass of 115 830 tonnes. An estimate for the catch-at-age and catch weight-at-age over the period November 2005 to October 2006 (listed in Table 1) was calculated by increasing these values proportionally, assuming the 2006 TAC of 204 000 tonnes will be caught before the end of October 2006.

7) The weight-at-age in the November 2004 and 2005 surveys, used to calculate the model predicted sardine SSB (Spawning Stock Biomass), was based on an average ALK from the November 1997 to 1999 surveys. The model predicted sardine SSB in November 2006 was calculated using the average November weight-at-age, which has been updated from the last assessment to include the data from 2004 and 2005. These weights-at-age are listed in Table 2.

The observed proportions-at-age in the November 2000 to 2003 surveys were not used to fit the model in Cunningham and Butterworth (2004a) and therefore the observed proportions-at-age in the November 2004 survey were similarly not included in this update. This is because, in the absence of recent annual ageing information, these proportions-at-age are based on an average ALK from the November 1997 to 1999 surveys. Models should be fit to more reliable "observed" data, to be obtained in due course from ALKs for the years concerned.

**Results**

The model fits to the November spawner biomass data at the posterior mode are shown in Figure 1 with the model fits to the May recruitment data at the posterior mode shown in Figure 2. The greater variability in recruitment in the sensitivity test results in a very close fit to the most recent recruitment observations, giving more credibility to this test compared to the base case. The sensitivity test provides a best estimate for the spawner biomass survey result in November 2006 of around 1.174 million tonnes. The percentage breakdown of this estimate is 29% 1-year-olds, 8% 2- and 3-year-olds, 30% 4-year-olds and 33% 5-year olds. Sampling 1000 values from the likelihood profile for this best estimate of 2+ biomass in November 2006 and combining with 1000 values of recruitment sampled using the May 2006 recruitment observation (described above), and assuming a survey sampling CV of 0.24, gives a distribution ranging from around 0.5 to 2.2 (95% probability interval from 0.661 to 1.963) million tonnes for the anticipated survey result (Figure 3).

*Potential Sardine TAC for 2007*

The 2006 sardine TAC is 204 000t, below the '2-tier' threshold in OMP-04. Thus OMP-04 would restrict any decline in the sardine TAC to a maximum of 15% from the previous year. If 1.174 million tonnes were observed in November 2006, OMP-04 would calculate the 2007 sardine TAC to be 173 400t. In the absence of this restriction in the inter-annual decline, the 2007 sardine TAC would be about 172 000t.

Applying OMP-04 to the sampled distribution of values in Figure 3 results in a 95% probability interval for the 2007 directed sardine TAC being 173 400t to 287 700t (median of 173 400t). The lower bound of this interval decreases to 96 900t in the absence of the above mentioned 15% restriction (Figure 4).

The threshold below which rules for exceptional circumstances are invoked for the sardine TAC is 250 000t. This threshold was never reached during the 1000 simulations performed for these analyses.

**Discussion**

This document has presented a coarse update to the sardine assessment, taking into account data available to June 2006. This assessment is not to be considered as comprehensive as the last assessment carried out by Cunningham and Butterworth (2004a) due to some assumptions regarding data listed in the text above (and particularly those relating to the lack of recent ageing information). Rather these results are intended only to provide a ball-park figure for the 2007 sardine TAC for the purposes of industry planning.

Of some concern is the high contribution of 4- and 5-year-olds to the predicted biomass in November 2006. This assessment is based on an assumed fixed adult natural mortality of 0.4 $year^{-1}$. If natural mortality has actually been higher the observed biomass could be lower than that predicted above, though such a change would modify other estimated parameters of the model which could lead to a compensating effect.

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**References**

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*Table 1. Sardine catch-at-age data by number (in millions), where $C^S_{y,a}$ is the catch-at-age a from 1 November in year y-1 to 31 October in year y, and where $w^S_{y,ac}$ is the weight-at-age a (in grams) in the catch from 1 November in year y-1 to 31 October in year y. Data for 1980 to 2003 are recorded in Cunningham and Butterworth (2004a).*

| Year | $C^S_{y,0}$ | $C^S_{y,1}$ | $C^S_{y,2}$ | $C^S_{y,3}$ | $C^S_{y,4}$ | $w^S_{y,0c}$ | $w^S_{y,1c}$ | $w^S_{y,2c}$ | $w^S_{y,3c}$ | $w^S_{y,4c}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 2004 | 3651.998 | 2448.166 | 977.583 | 436.332 | 69.482 | 31.91 | 58.77 | 74.49 | 75.60 | 87.25 |
| 2005 | 1650.824 | 1740.167 | 1130.286 | 490.777 | 81.747 | 32.00 | 64.97 | 78.83 | 79.04 | 88.26 |
| 2006 | 1044.470 | 650.402 | 704.002 | 319.215 | 64.261 | 10.84 | 69.10 | 80.87 | 81.61 | 88.66 |

*Table 2. Sardine mean masses-at-age, $w^S_{y,a}$, observed during the November spawner biomass survey. For years in which the mass-at-age is not available (i.e. 1984 to 1987 and 2006), the average mass-at-age, $\overline{w}^S_a$, is used. Data for 1980 to 2003 are recorded in Cunningham and Butterworth (2004a).*

| Year | $w^S_{y,1}$ | $w^S_{y,2}$ | $w^S_{y,3}$ | $w^S_{y,4}$ | $w^S_{y,5}$ |
|---|---|---|---|---|---|
| 2004 | 32.64 | 79.25 | 85.71 | 92.61 | 103.02 |
| 2005 | 38.69 | 79.10 | 87.85 | 94.01 | 101.28 |
| Average | 34.67 | 71.05 | 85.99 | 96.47 | 108.35 |

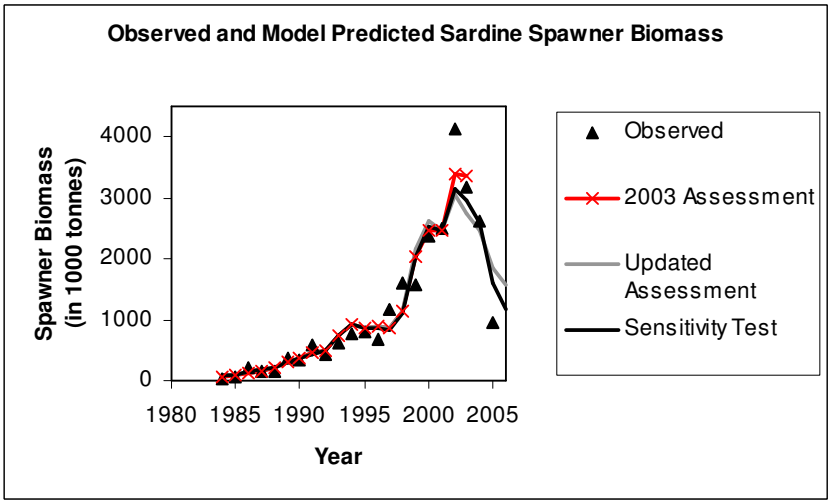


*Figure 1. Observed and model predicted uncapped November sardine spawner biomass from November 1984 to November 2006 from the updated assessment and sensitivity test described in this document. The predicted spawner biomass from November 1984 to November 2003 from Cunningham and Butterworth (2004a), as used in developing the current OMP, is included for comparison.*

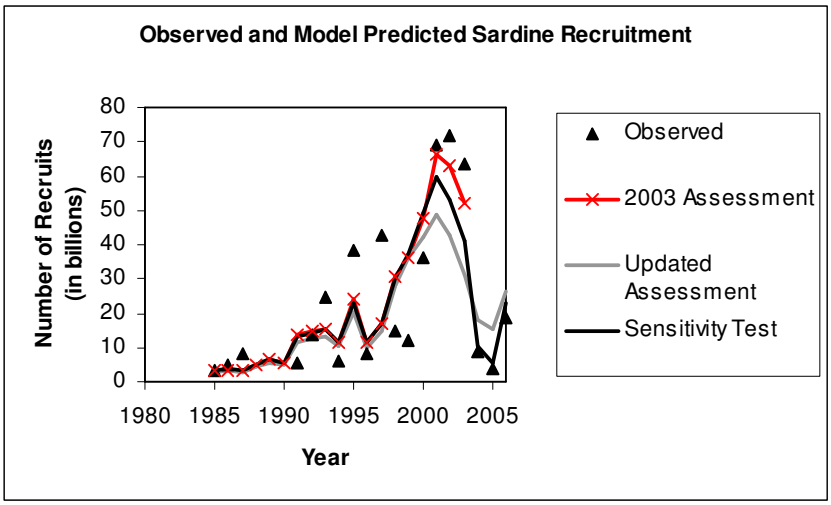


*Figure 2. Observed and model predicted uncapped sardine recruitment numbers from May 1985 to May 2006 from the updated assessment and sensitivity test described in this document. The predicted recruitment from May 1985 to May 2003 from Cunningham and Butterworth (2004a) is included for comparison.*

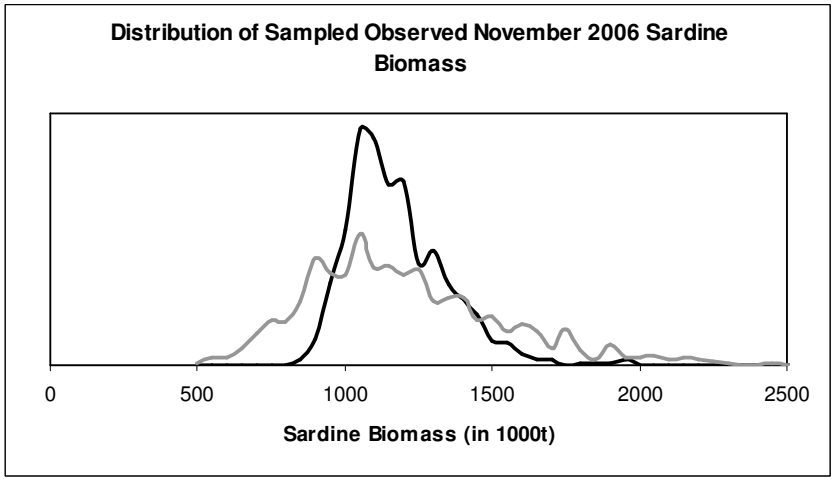


*Figure 3. The distribution of predicted sardine biomass in November 2006, generated using the method described in the text (black line), and as may be observed taking a survey sampling CV of 0.24 into account (grey line).*

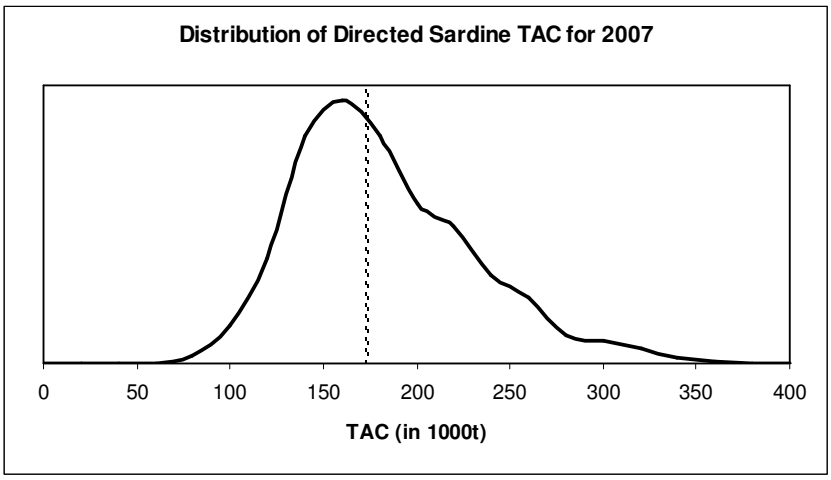


*Figure 4. The distribution of predicted directed sardine TAC for 2007, generated from the distribution of predicted sardine biomass in November 2006 given in Figure 3, without the 15% maximum inter-annual reduction in the directed sardine TAC. Applying the 15% maximum inter-annual restriction leaves only that part of the distribution to the right of the vertical dashed line, together with a 57% chance that the directed sardine TAC in 2007 would be 173 400t.*