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Revised estimates of abundance of South African sardine and anchovy from acoustic surveys adjusting for echosounder saturation in earlier surveys and attenuation effects for sardine

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Hydro-acoustic surveys have been used to provide annual estimates of May recruitment and November spawner biomass of the South African sardine *Sardinops sagax* and anchovy *Engraulis encrasicolus* resources since 1984. These time-series of abundance estimates form the backbone of the assessment of these resources, and consequently the management of the South African sardine and anchovy is critically dependent on them. Upgrades to survey equipment over time have resulted in recent surveys providing more accurate estimates of abundance, yet in order to maintain comparability across the full time-series, estimates of biomass mimicking the old equipment were used for a number of years. In this paper we develop a method to revise the earlier part of the time-series to correct for receiver saturation in the older generation SIMRAD EK400 and EKS-38 echosounders and to account for attenuation in dense sardine schools. This is applied to provide a revised time-series of biomass estimates for the South African sardine and anchovy resources with associated variance–covariance matrices. Furthermore, the time-series presented here are based on updated acoustic target strength estimates, making this the most reliable time-series currently available for both resources.

Keywords: acoustic survey, anchovy, attenuation, calibration adjustment, regression, sardine, saturation

Introduction

Management of the South African sardine *Sardinops sagax* and anchovy *Engraulis encrasicolus* resources is critically dependent on estimates of recruitment and spawner biomass obtained from hydro-acoustic surveys, which commenced in 1984 (Hampton 1992, Geromont *et al*. 1999, De Oliveira and Butterworth 2004). The recruit surveys take place in May and spawner biomass surveys in November; for ease of distinction, May and November will be used to distinguish these two surveys hereafter. Figure 1 demonstrates the typical coverage undertaken during the surveys. The standard November survey area stretches from Hondeklip Bay on the South African west coast to Port Alfred on the South Coast, whereas the standard May survey area stretches from the Orange River to Cape Infanta on the South Coast to cover the distribution range of recruits at that time. In former years, the surveys did not necessarily cover this whole area (coincident with a lower biomass and more limited distribution of the resources), whereas in recent years the surveys have extended farther eastwards with an increase in sampling effort on the Central and Eastern Agulhus Bank. To enable the estimation of sampling variance without bias, a stratified random survey design is used. Each survey is divided into strata chosen with the intent of minimising inter-transect variance. During the earlier surveys, these strata were respecified to take account of knowledge gained about the distribution and density variation of anchovy, the larger of the two resources over that period. However, during the latter part of the time-series, strata were kept unchanged from year to year to facilitate comparisons of abundance in specific strata over time.

In 1997, new equipment, a SIMRAD EK500 echosounder, replaced the older SIMRAD EK400 echosounder. This revealed that receiver saturation had occurred in the SIMRAD EK400 and probably also in previous generation echosounders, particularly for sardine (Barange *et al.* 1999, Coetzee *et al*. 2008). Essentially, the EK400 saturated at approximately –29 dB, thereby setting any signal higher than –29 dB to –29 dB, i.e. it 'capped' signals at this maximum level (the EK500 uses newer technology which excludes the possibility of saturation). Saturation in the SIMRAD EKS-38,

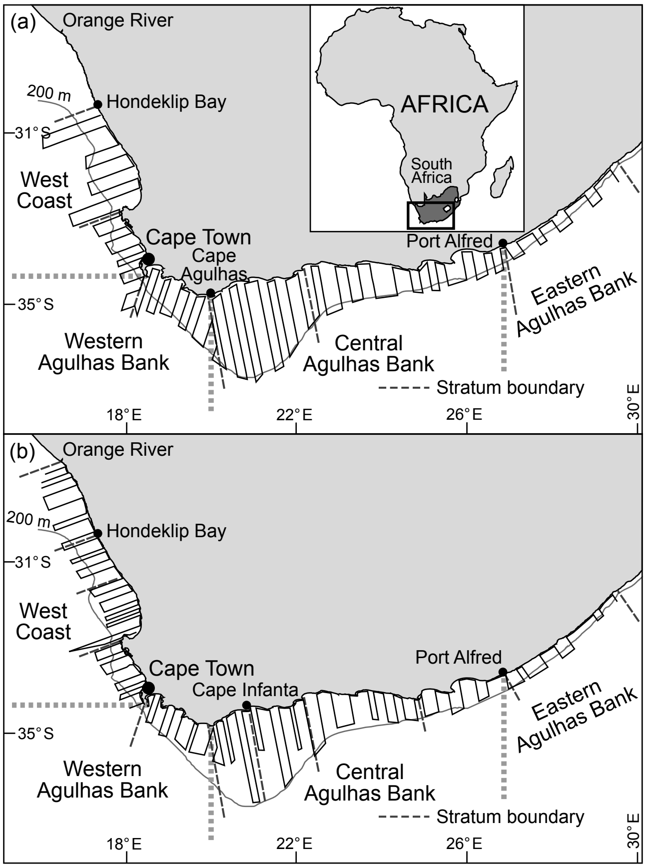

Figure 1: Track chart for a typical (a) November and (b) May hydro-acoustic survey off the coast of South Africa. Each survey is divided into strata chosen to minimise inter-transect variance

which was used prior to the SIMRAD EK400, is assumed to have occurred at the same level as in the EK400. For simplicity, only the EK400 is mentioned hereafter, but this signifies reference to previous generation echosounders as well. Initially, to maintain a comparable time-series, abundance estimates derived from surveys from 1997 onwards were artificially adjusted by setting the maximum signal threshold of the SIMRAD EK500 data to –29 dB at the analysis stage, to provide comparable 'capped' estimates of biomass.

Although this provided a temporary solution to the difference in estimates between the SIMRAD EK400 and EK500, for the longer term it was not considered satisfactory to continue to ignore the improved data provided by the SIMRAD EK500. It was therefore recommended that the survey estimates of abundance used for assessment purposes be based rather on the SIMRAD EK500 technology (BENEFIT 2001); these are referred to here as 'uncapped' estimates. This required that the pre-1997 survey results be adjusted to allow for the impact of the saturation effect.

This paper details the method developed to revise the time-series of abundance estimates over the period 1984–1997. Essentially, a non-linear regression analysis of the capped densities as they are related to the uncapped densities is carried out for the period 1997–2006, for which comparative fish density estimates based on both the SIMRAD EK500 uncapped and simulated SIMRAD EK400 capped data are available. The results are used to adjust the pre-1997 estimates, and to revise the associated estimates of precision taking account of variability about the calibration adjustment relationships as well as imprecision in the estimation of these relationships.

This exercise has been conducted taking two further factors into account. First, more appropriate acoustic target strength estimates for sardine and anchovy that were not available at the start of the time-series have become available (Hampton 1987, Barange *et al*. 1996) and have recently been incorporated into the biomass estimates (Coetzee *et al*. 2008). Both the capped and uncapped data used for these analyses are based on the density estimates derived from these updated target strength densities.

Second, in dense fish schools, fish at the top of the school absorb most of the energy from acoustic echo signals so that fish lower down in the school are insonified with less energy, resulting in the echo signals no longer being proportional to fish density. The effect of this signal attenuation in dense sardine schools has been quantified (Coetzee *et al*. 2008) and a correction factor to account for attenuation has been routinely applied to sardine school density estimates since 1998 (Coetzee *et al*. 2008). The calibration adjustment for sardine thus accounts for attenuation as well as for the saturation effect. Because the attenuation adjustments are possible only from 1998 onwards, the calibration adjustment relationships for sardine are based on data from 1998 rather than 1997 onwards, with the capped 1997 estimates thus also subject to modification by this calibration adjustment.

Material and Methods

Data

The data used to determine the calibration adjustment relationships required for anchovy are the capped estimates of density per interval (Elementary Sampling Distance Unit [ESDU], a short segment of a survey transect line varying in length but usually shorter than 10 nautical miles) and the uncapped estimates of these densities for the May recruit and November spawner biomass surveys from November 1997 to May 2006. For sardine, attenuation was taken into account in the uncapped, but not the capped estimates, and surveys from May 1998 to May 2006 were considered when estimating calibration adjustment relationships. Capped interval densities, from which uncapped densities are to be estimated, are available for anchovy from November 1984 to May 1997 and for sardine from November 1984 to November 1997.

Regression of the capped data on the uncapped data

Both the uncapped and capped survey estimates of biomass are subject to survey sampling error. However, the uncapped estimates are free from the further error caused by the saturation problem associated with the SIMRAD EK400. In addition, for sardine, the uncapped estimates are also free from further error due to attenuation at large densities. Therefore, the uncapped data are the only set of unbiased observed data. (Note that in the context of estimating the capped:uncapped calibration adjustment factors, the survey sampling error is not of direct relevance because the comparisons being made are between capped and uncapped estimates (with attenuation for sardine) for the same segment of survey transect line.)

A bootstrap procedure was used to estimate the variance associated with the calibration adjustment, as detailed later. In generating replicate data, to be realistic the ratios ('slope') of capped to uncapped estimates for each interval must lie in the [0,1] range. To respect these bounds, the calibration adjustment regressions were performed on a logit transformation of slope (capped:uncapped) against uncapped densities. This transformed value is denoted hereafter as 'lslope'. These regressions were performed separately for the May and November surveys, and independently for sardine and anchovy.

A mixture model was used so that the data for intervals for which slope is 1, which comprise a substantial proportion of the data, could be treated separately than those for intervals with slope <1. The mixture model thus consists of a component that fits a model to estimate the probability that the observed slope is 1, and a component that fits a model for lslope, as a function of uncapped density, in cases where slope <1.

Models, which consisted of various combinations of constants, straight lines, and negative exponential curves, were fit to the relation between the probability that the slope = 1 ($\text{prop}_{y,i}^{\text{slope}=1}$), for interval i in year y) and the uncapped density. Transition points for switching between the different curves were fixed in some instances and estimated in others. A binomial error distribution was assumed. Thus, the negative log-likelihood that was minimised to estimate the model parameters was,

$$-\ln L = \sum_y \sum_i \left[-\delta_{y,i} \log(\text{prob}_{y,i}^{\text{slope}=1}) - (1-\delta_{y,i}) \log(1-\text{prob}_{y,i}^{\text{slope}=1}) \right]$$

where $$\delta_{y,i} = \begin{cases} 1 & \text{if} \quad u_{y,i} = c_{y,i} \\ 0 & \text{if} \quad u_{y,i} \neq c_{y,i} \end{cases}$$

and $u_{y,i}$ denotes the observed uncapped density in interval i of year y and $c_{y,i}$ the corresponding capped density. Using Akaike's Information Criterion (AIC) to compare between models, and looking also to apply the same model to all four sets of data, the following model (consisting of three straight lines followed by a constant) was eventually chosen:

$$\text{prob}_{y,i}^{\text{slope}=1} = \begin{cases} m^{*} u_{y,i} + b & \text{if } u_{y,i} \le u^{*} \\ m^{**}\left(u_{y,i} - u^{*}\right) + m^{*}u^{*} + b & \text{if } u^{*} \le u_{y,i} \le u^{**} \\ \dfrac{m^{**}\left(u^{**} - u^{*}\right) + m^{*}u^{*} + b - p}{u^{**} - u^{***}}\left(u_{y,i} - u^{***}\right) + p & \\ & \text{if } u^{**} \le u_{y,i} \le u^{***} \\ p & \text{if } u_{y,i} \ge u^{***} \end{cases} \qquad (1)$$

where $\underline{\theta}$ = {m^*, m^{**}, b, p, u^*, u^{**}, u^{***}} is the vector of estimable parameters. Although a slightly better model fit in terms of AIC was obtained when u^{***} was initially fixed, this seemed an inappropriate basis for choice in this instance because the fixed value selected was somewhat arbitrary.

The models considered when regressing the logit transformed slope against uncapped densities when slope <1 included:

(i) a linear model:

$$\text{lslope}_{y,i} = m_1$$

(ii) a '2-line (gradient)' model:

$$\text{lslope}_{y,i} = \begin{cases} m_1\left(u_{y,i} - u_1\right) + b_1 & 0 < u_{y,i} \le u_1 \\ m_2\left(u_{y,i} - u_1\right) + b_1 & u_{y,i} > u_1 \end{cases}$$

(iii) a '2-line (const large u)' model:

$$\text{lslope}_{y,i} = \begin{cases} m_1\left(u_{y,i} - u_1\right) + b_1 & 0 < u_{y,i} \le u_1 \\ b_1 & u_{y,i} > u_1 \end{cases}$$

(iv) a '2-line (const small u)' model:

$$\text{lslope}_{y,i} = \begin{cases} b_1 & 0 < u_{y,i} \le u_1 \\ m_2\left(u_{y,i} - u_1\right) + b_1 & u_{y,i} > u_1 \end{cases}$$

(v) a 'Beverton-Holt (BH) type' model:

$$\text{lslope}_{y,i} = \frac{\alpha}{1+\beta u_{y,i}}$$

(vi) a 'Beverton-Holt (BH) adjusted type' model:

$$\text{lslope}_{y,i} = \begin{cases} \dfrac{\alpha}{1+\beta u_{y,i}} & 0 < u_{y,i} \le u_1 \\ \dfrac{\alpha}{1+\beta u_1} & u_{y,i} > u_1 \end{cases}$$

Model (iv) needed to be considered only for the anchovy May survey as a means to force a non-positive gradient for small u. Although a number of different error structures were initially investigated, those with a variance independent of uncapped density u (i.e. errors with a distribution $N(0,\sigma^2)$ added to the above equations) were generally found to be adequate for regressing lslope against u. However, initial results did indicate that the variance around the fitted relation could change above a certain value of u. Therefore, two different error models were considered:

(a) constant variance:

$$\sigma_{y,i}(u_{y,i}) = \sigma$$

(b) changing variance:

$$\sigma_{y,i}\left(u_{y,i}\right) = \begin{cases} \sigma & \text{if } u_{y,i} \le u_2 \\ \delta\sigma & \text{if } u_{y,i} > u_2 \end{cases} \qquad \text{where } \delta = \text{constant.}$$

The parameters estimated were thus a subset of $\underline{\phi}$ = {m_1, m_2, b_1, u_1, α, β, σ, δ} (dependent on the Models (i)–(vi) and variance formulation (a) or (b) chosen). The transition point for change in variance u_2 was fixed using the best fit from a grid of width 50 g m^{-2}. A normal likelihood was used to fit the model predicted lslope to the observed data for which slope <1:

$$-\ln L = 0.5 \sum_y \sum_i \left[\ln\left(\left(\sigma_{y,i}\left(u_{y,i}\right)\right)^2\right) + \frac{\left(\ln\left(\frac{c_{y,i}/u_{y,i}}{1-c_{y,i}/u_{y,i}}\right) - \text{lslope}_{y,i}\right)^2}{\left(\sigma_{y,i}\left(u_{y,i}\right)\right)^2} \right] + \text{const}$$

$$\text{for } c_{y,i} < u_{y,i} \qquad (2)$$

Calibration adjustment of uncapped data from capped data

The mixture model chosen above gives an expected capped density $c_{y,i}$ from a given uncapped density as:

$$c_{y,i} = f\left(\underline{\theta}, \underline{\phi}, u_{y,i}\right)$$
$$= \text{prob}_{y,i}^{\text{slope}=1} \times u_{y,i} + \left(1 - \text{prob}_{y,i}^{\text{slope}=1}\right) \times u_{y,i} \times \frac{e^{\text{lslope}_{y,i}}}{1+e^{\text{lslope}_{y,i}}} \qquad (3)$$

This equation can be inverted to solve non-linearly for $u_{y,i}$, i.e.:

$$u_{y,i} = g\left(\underline{\theta}, \underline{\phi}, c_{y,i}\right) \qquad (4)$$

given the capped interval densities in the early years.

To calculate the annual biomass estimate, the mean biomass and density per strata need to be calculated, which requires the mean density per transect to be computed (Jolly and Hampton 1990). Defining $u_{y,s,t,i}$ to denote the uncapped estimate in interval i of transect t of stratum s in year y, $l_{s,t,i}$ to denote the length of interval i of transect t of stratum s, and $L_{s,t} \neq \sum_i l_{s,t,i}$[1] to denote true length of transect t of stratum s, the mean density per transect t is calculated as:

$$\bar{u}_{y,s,t} = \frac{\sum_i u_{y,s,t,i} l_{s,t,i}}{\sum_i l_{s,t,i}} \qquad (5)$$

The estimated mean density per stratum s is calculated as:

$$\bar{u}_{y,s} = \frac{\sum_t \bar{u}_{y,s,t} L_{s,t}}{\sum_t L_{s,t}} \qquad (6)$$

and the associated standard error and CV is:

$$\text{SE}^{\text{samp}}\left(\bar{u}_{y,s}\right) = \sqrt{\frac{\frac{T_{y,s}}{T_{y,s}-1} \sum_{t=1}^{T_{y,s}} \left[\left[\left(\bar{u}_{y,s,t} - \bar{u}_{y,s}\right) L_{s,t}\right]^2\right]}{\left[\sum_{t=1}^{T_{y,s}} L_{s,t}\right]^2}}$$

and

$$\text{CV}^{\text{samp}}\left(\bar{u}_{y,s}\right) = \frac{\text{SE}^{\text{samp}}\left(\bar{u}_{y,s}\right)}{\bar{u}_{y,s}} \qquad (7)$$

where $T_{y,s}$ denotes the total number of transects in stratum s in year y, and the superscript 'samp' is used to denote that this arises from the sampling nature of the transects surveyed in the stratum. Inshore areas, which comprise 5–7% of the total area covered by the surveys in November and 8–10% in May, are too shallow to be safely surveyed by the research vessel. The assumption is made that the average densities in these areas is half that estimated during the inshore transits between transects in the particular stratum (Hampton 1987).

The estimated stratum biomass is then

$$B_{y,s} = \bar{u}^*_{y,s} \times \text{Area}_{y,s} \qquad (8)$$

where $\bar{u}^*_{y,s} = \begin{cases} \bar{u}_{y,s} & \text{if } s \text{ is offshore} \\ 0.5\,\bar{u}_{y,s} & \text{if } s \text{ is inshore} \end{cases}$

The annual biomass, average density and associated CV are then calculated as:

$$B_y = \sum_{s=1}^{S_y} B_{y,s}\,, \qquad u_y = \frac{\sum_{s=1}^{S_y} \bar{u}^*_{y,s} \times \text{Area}_{y,s}}{\sum_{s=1}^{S_y} \text{Area}_{y,s}} \qquad \text{and}$$

$$\text{CV}^{\text{samp}}\left(B_y\right) = \frac{\sqrt{\sum_{s=1}^{S_y} \text{Var}\left(B_{y,s}\right)}}{B_y} = \text{CV}^{\text{samp}}\left(u_y\right) \qquad (9)$$

where S_y denotes the total number of strata in year y.

Accounting for further sources of uncertainty

Equations (7) and (9) account for inter-transect variability and are applied in cases where the $u_{y,s,t,i}$ are observed. However, there are two further sources of uncertainty that need to be taken into account: error in the calibration adjustment of $c_{y,s,t,i}$ to obtain $u_{y,s,t,i}$ using Equation (4), and uncertainty in the estimates of the parameter estimates ($\underline{\theta}$ and $\underline{\phi}$) themselves. These sources of uncertainty must also be incorporated.

Error in the calibration adjustment was estimated by bootstrapping over r = 1,2…R = 10 000 replicates of $u_{y,s,t,i}$, given estimates for the parameters $\underline{\theta}$ and $\underline{\phi}$, as follows:

(i) Generate $\quad \text{lslope}^r_{y,i} \sim N\left(\text{lslope}_{y,i}, \left(\sigma_{y,i}\left(u_{y,i}\right)\right)^2\right)$

(ii) $\quad s^r_{y,i} = \frac{e^{\text{lslope}^r_{y,i}}}{1+e^{\text{lslope}^r_{y,i}}}$

(iii) Generate $\quad x^r \sim U\left[0,1\right]$

[1] The true transect length is the actual distance of the transect over land, which may differ from the summed interval length per transect. Interval length is obtained from the ship's log which measures distance through water and which will be a biased estimate of true interval length when current speed is not zero

(iv) $$u^r_{y,s,t,i} = \begin{cases} c_{y,s,t,i} & \text{if } x^r < \text{prob}^{\text{slope}=1}_{y,i} \\ \dfrac{c_{y,s,t,i}}{s^r_{y,i}} & \text{if } x^r \geq \text{prob}^{\text{slope}=1}_{y,i} \end{cases}$$

(v) Generate $\bar{u}^r_{y,s,t}$, $\bar{u}^r_{y,s}$ and $\text{CV}^{\text{samp}}(\bar{u}^r_{y,s})$ using Equations (5), (6) and (7).

The average inter-transect CV over all the bootstraps is then:

$$\text{CV}^{\text{samp}}_{\text{avg}}\left(\bar{u}_{y,s}\right) = \frac{1}{R}\sum_{r=1}^{R}\text{CV}^{\text{samp}}\left(\bar{u}^r_{y,s}\right) \quad (10)$$

The average bootstrap estimate for the average uncapped density in stratum s of year y would then be:

$$\bar{\bar{u}}_{y,s} = \frac{1}{R}\sum_{r=1}^{R}\bar{u}^r_{y,s} \quad (11)$$

The associated standard error and CV related to calibration adjustment uncertainty are therefore:

$$\text{SE}_{\text{cal}}\left(\bar{\bar{u}}_{y,s}\right) = \sqrt{\frac{1}{R-1}\sum_{r=1}^{R}\left[\left(\bar{u}^r_{y,s} - \bar{\bar{u}}_{y,s}\right)^2\right]},$$

$$\text{CV}_{\text{cal}}\left(\bar{\bar{u}}_{y,s}\right) = \frac{\text{SE}\left(\bar{\bar{u}}_{y,s}\right)}{\bar{\bar{u}}_{y,s}} \quad (12)$$

The combined CV for the estimated average uncapped density in stratum s of year y, taking inter-transect and calibration adjustment error into account, is therefore given by the standard formula for the variance of the product of two independent quantities:

$$\text{CV}^{\text{tot}}_{y,s} = \sqrt{\text{CV}_{\text{cal}}\left(\bar{\bar{u}}_{y,s}\right)^2 + \text{CV}^{\text{samp}}_{\text{avg}}\left(\bar{u}_{y,s}\right)^2 + \text{CV}_{\text{cal}}\left(\bar{\bar{u}}_{y,s}\right)^2\text{CV}^{\text{samp}}_{\text{avg}}\left(\bar{u}_{y,s}\right)^2} \quad (13)$$

and using the uncapped stratum biomass from Equation (8) and annual biomass from Equation (9), the annual CV taking inter-transect and calibration adjustment error into account is accordingly:

$$\text{SE}^{\text{tot}}\left(B_y\right) = \sqrt{\sum_{s=1}^{S_y}\left(\text{CV}^{\text{tot}}_{y,s}\times B_{y,s}\right)^2}, \quad \text{CV}^{\text{tot}}\left(B_y\right) = \frac{\text{SE}^{\text{tot}}\left(B_y\right)}{B_y} \quad (14)$$

Note that $\text{CV}^{\text{tot}}_{y,s}$ is taken to apply to the original biomass rather than the average bootstrapped biomass.

The uncertainty in the parameter estimates of $\underline{\theta}$ and $\underline{\phi}$ was taken into account by calculating a jackknife estimate of variance[2] of B_y according to Efron (1982):

$$\text{Var}\left(\hat{B}_y\right) = \frac{n-1}{n}\sum_{yr=1}^{n}\left(\hat{B}_{-yr} - B_{(\,)}\right)^2 \quad (15)$$

where $\hat{B}_{-yr}$ denotes the estimate of B_y computed by omitting the data from year yr in the estimation of $\underline{\theta}$ and $\underline{\phi}$, whereas $B_{(\,)}$ denotes the mean of the $\hat{B}_{-yr}$s. The associated CV is then:

$$\text{CV}\left(\hat{B}_y\right) = \frac{\sqrt{\text{Var}\left(\hat{B}_y\right)}}{B_y} \quad (16)$$

The CV for the annual biomass estimate calculated in Equation (9) taking into account inter-transect, calibration adjustment and parameter estimation uncertainty, is therefore given by:

$$\text{CV}\left(B_y\right) = \sqrt{\text{CV}^{\text{tot}}\left(B_y\right)^2 + \text{CV}\left(\hat{B}_y\right)^2 + \text{CV}^{\text{tot}}\left(B_y\right)^2\text{CV}\left(\hat{B}_y\right)^2} \quad (17)$$

The fact that this last source of error is common to all years subject to the calibration adjustment introduces covariance into the time-series of uncapped estimates of biomass. These covariances need to be estimated, because they are elements of the variance-covariance matrix needed in calculating the likelihood of the survey series of estimates, which is maximised when fitting population models to these data. Let

$$\text{RV}\left(B_{yi,yj}\right) = \frac{\text{Cov}\left(B_{yi}, B_{yj}\right)}{B_{yi}B_{yj}}$$

denote the relative variance–covariance matrix taking inter-transect and calibration adjustment error into account. This is a diagonal matrix because the estimates each year can be considered to be independent and the diagonal entries are $(\text{CV}^{\text{tot}}(B_y))^2$. Let

$$\text{RV}\left(\hat{B}_{yi,yj}\right) = \frac{\text{Cov}\left(\hat{B}_{yi}, \hat{B}_{yj}\right)}{B_{yi}B_{yj}}$$

denote the relative jackknife variance–covariance matrix arising from parameter estimation uncertainty in the capping calibration adjustment relationships. The diagonal entries are $(\text{CV}(\hat{B}_y))^2$. Taking the sources of the variances of B_y and $\hat{B}_y$ to be independent[3], the relative variance–covariance matrix for $\underline{B}$ is then calculated as follows:

$$\text{RV}\left(B_{yi,yj}\right) = \text{RV}\left(B^{\text{tot}}_{yi,yj}\right) + \text{RV}\left(\hat{B}_{yi,yj}\right) + \text{RV}\left(B^{\text{tot}}_{yi,yj}\right)\times\text{RV}\left(\hat{B}_{yi,yj}\right)$$

which can be re-written as

$$\text{RV}\left(B_{yi,yj}\right) = \begin{cases} \text{RV}\left(B^{\text{tot}}_{yi,yj}\right) + \text{RV}\left(\hat{B}_{yi,yj}\right) + \text{RV}\left(B^{\text{tot}}_{yi,yj}\right)\times \\ \quad \text{RV}\left(\hat{B}_{yi,yj}\right) & \text{if } i = j \\ \quad\quad \text{RV}\left(\hat{B}_{yi,yj}\right) & \text{if } i \neq j \end{cases}$$

[2] A sampling unit of a year was chosen to counter possibilities of non-independence of data within a given year. The jackknife was preferred to a bootstrap approach to reduce the computational burden

[3] Strictly, this is not the case because the data used for the latter contribute to the estimate of variability about the relationship between lslope and u in the former, but this effect does not seem likely to be large

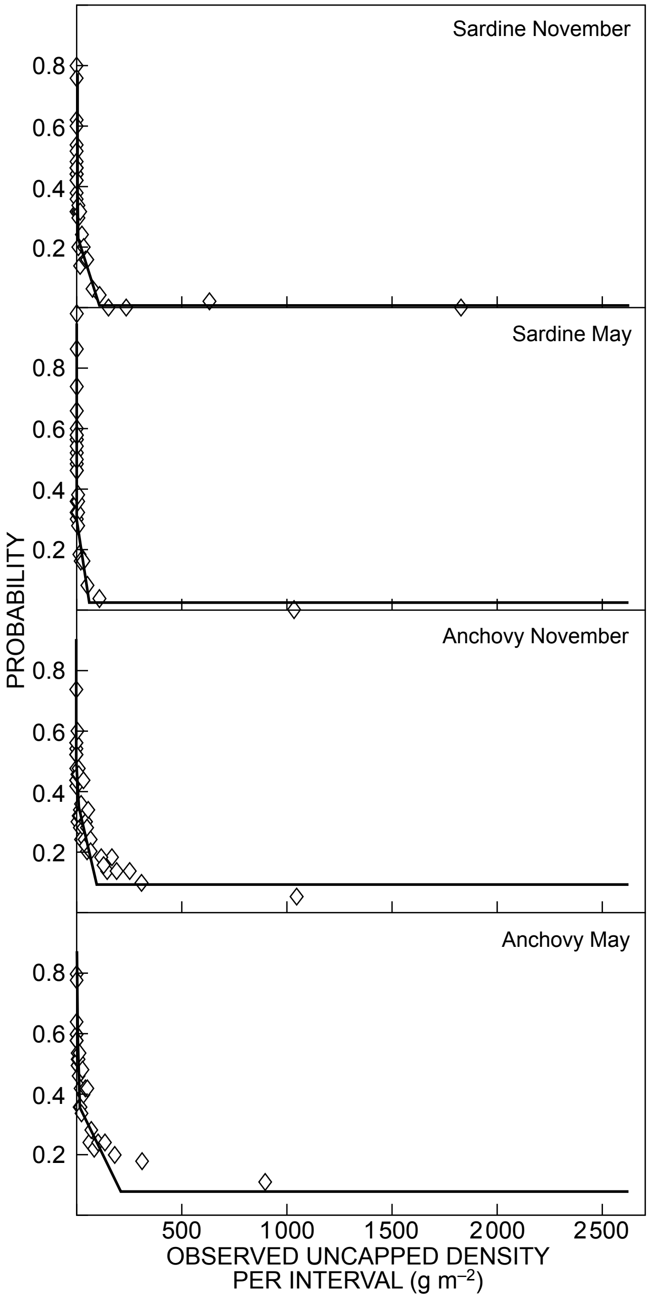

Figure 2: The model estimated probability that slope (the ratio capped:uncapped) is 1, from Equation (1). For comparative purposes, the observed probability that slope is 1 is also plotted in bins of 50 data points at a time

Results and Discussion

The model fits to the probability that the observed slope is 1 are given in Figure 2, with the estimated model parameter values given in Table 1.

Table 2 lists the AIC values for combinations of Models (i)–(vi) and error structures (a) and (b) defined above. In all cases, the AIC model selection criterion showed the changing error variance option to perform better than the constant variance option.

The 2-line (gradient) model had the lowest AIC value for the sardine November survey, but the fitted model resulted in capped density decreasing at large uncapped density, which is unrealistic for the relationship that must sensibly be monotonic. The BH-adjusted type model (which by construction avoids this problem) was thus chosen, manifesting a good fit to the data (Figure 3) and the second lowest AIC value. For the sardine May survey, the BH type model resulted in a good fit to the data (Figure 4). The inclusion of the extra parameter in the BH-adjusted type model did not result in a substantial improvement in the fit, so that the AIC model selection criterion favoured the BH type model.

For anchovy May and November surveys, the 2-line (gradient) model had the lowest AIC value. However, the estimated gradient of slope vs u was (marginally) positive for lower uncapped densities for the May survey and positive for higher uncapped densities for the November survey. This positive gradient implies that, for a given increase in uncapped density, there is an even greater increase in capped density. Both such dependencies seem unrealistic, even though (weakly) supported by the data. For the anchovy November survey, the BH-adjusted type model was thus chosen, having the second lowest AIC value and a good fit to the data (Figure 5). For the anchovy May survey, although the 2-line (const small u) model was the second-best model choice in terms of AIC, it was decided to use the BH type model (which had a similar AIC value) to maintain consistency with the other three cases (Figure 6).

The model fits to the observed lslope and the consequent 'regression' of capped against uncapped densities per interval are shown in Figures 3–6. The maximum likelihood estimates of the parameters are given in Table 3. The standardised residuals did not suggest any obvious model misspecification (plots not shown).

Probability density functions (pdfs) of the standardised residuals resulting from the likelihood in Equation (2) are given in Figure 7, together with comparisons to the pdfs

Table 1: Parameter estimates for the model that predicts the probability that the observed slope is 1. The uncapped density transition points are given in g m^{-2}

Parameter		Sardine November	Sardine May	Anchovy November	Anchovy May
m^*	Slope of straight line when $u \le u^*$	–4.1	–13.5	–27.3	–26.1
m^{**}	Slope of straight line when $u^* \le u \le u^{**}$	–0.018	–0.247	–0.014	–0.015
b	Probability-axis intercept for straight line when $u \le u^*$	0.79	0.99	0.98	0.99
p	Constant probability when $u \ge u^{***}$	0.006	0.020	0.093	0.078
u^*	1st transition point	0.086	0.030	0.016	0.014
u^{**}	2nd transition point	12.3	1.2	12.9	17.5
u^{***}	3rd transition point	109.8	55.2	96.7	208.5

of the standardised residuals for the same models, but without using a logit transformation in Equation (2). In all four cases, it is clear that the logit transformation provides the additional benefit of securing residuals that are less skew than would have been obtained had no transformation been used, and hence more consistent with the assumption of normality underlying the formulation of the likelihood in Equation (2).

Table 2: AIC values for a combination of models and error structures for lslope, given that observed slope <1. The values in bold are the lowest and those in *shaded italics* correspond to the model chosen

	Model					
	Linear	2-line (gradient)	2-line (const large *u*)	2-line (const small *u*)	BH type	BH-adjusted type
			Constant variance (a)			
Sardine November	2 781.7	2 413.0	2 411.0		2 415.8	2 414.1
Sardine May	2 076.3	1 965.5	1 936.8		1 920.5	1 922.5
Anchovy November	3 127.5	3 125.6	3 125.3		3 124.5	3 125.5
Anchovy May	2 210.3	2 209.0	2 210.4	2 212.9	2 212.3	2 214.4
			Changing variance (b)			
Sardine November		**2 334.9**	2 351.8		2 350.9	*2 342.9*
Sardine May		1 930.2	1 929.3		***1 904.9***	1 906.4
Anchovy November		**3 112.7**	3 119.7		3 119.0	*3 117.6*
Anchovy May		**2 204.4**	2 204.9	2 206.7	*2 205.9*	2 207.9

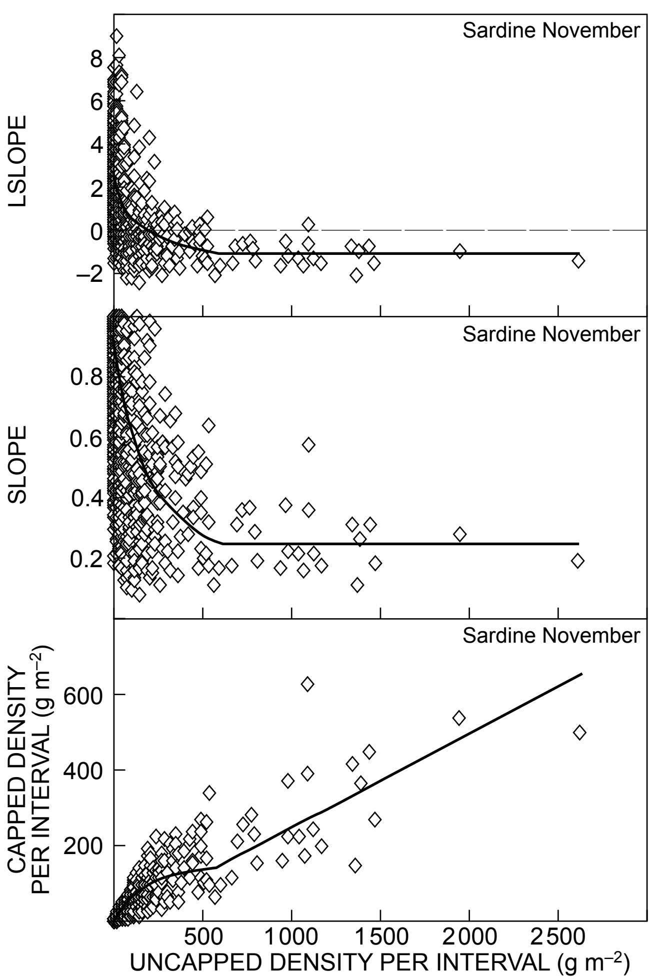

Figure 3: The model fits to the observed lslope and the consequent slope and 'regression' of capped against uncapped densities per interval for the sardine November survey, using the BH-adjusted type model with changing variance

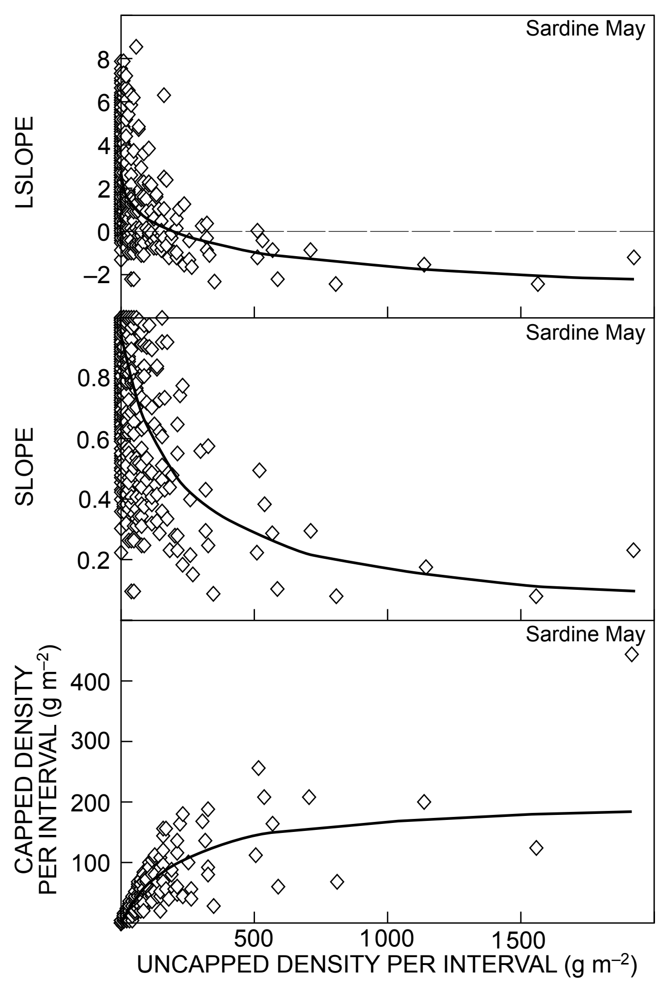

Figure 4: The model fits to the observed lslope and the consequent slope and 'regression' of capped against uncapped densities per interval for the sardine May survey, using the BH type model with changing variance

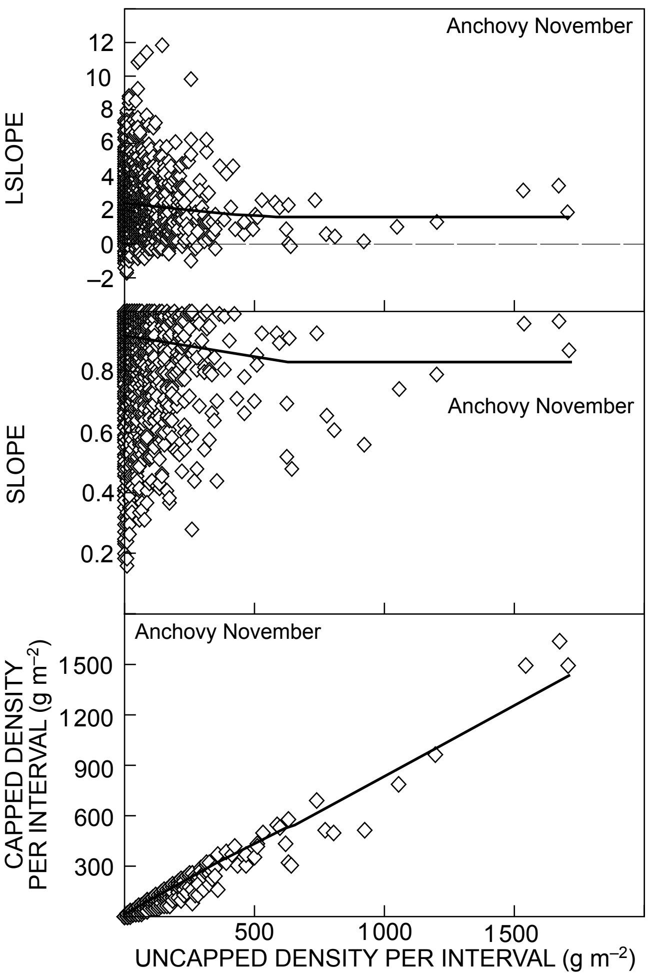

Figure 5: The model fits to the observed lslope and the consequent slope and 'regression' of capped against uncapped densities per interval for the anchovy November survey, using the BH-adjusted type model with changing variance

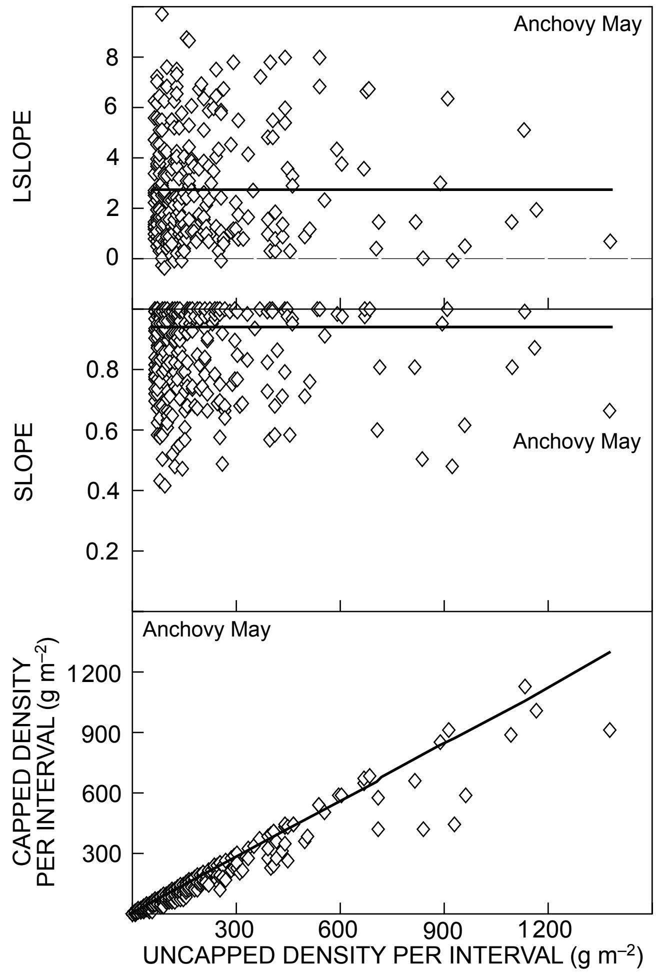

Figure 6: The model fits to the observed lslope and the consequent slope and 'regression' of capped against uncapped densities per interval for the anchovy May survey, using the BH type model with changing variance

Table 3: Maximum likelihood parameter estimates for the model for lslope, given that observed slope <1. The values for u_2 were fixed

Parameter		Sardine November	Sardine May	Anchovy November	Anchovy May
α	BH type model parameter	0.93	0.93	0.92	0.94
β	BH type model parameter	0.0047	0.0046	0.0002	0.0000
u_1	Transition point for change of gradient (g m^{-2})	577.9		642.6	
σ	Standard deviation estimate for lslope	1.78	1.84	1.85	1.96
δ	Multiplicative change in standard deviation	0.53	0.48	0.55	1.21
u_2	Density at which variance changes (g m^{-2})	150	200	450	150

Tables App.1.1–1.4 list the annual capped and uncapped density and biomass calculated using the calibration adjustment of Equation (4), together with the CV calculated from Equation (17). The full series is given for completeness. These results are given for the area used in the assessments (i.e. west of Port Alfred for the November survey and west of Cape Infanta for the May survey). The uncapped biomass and CV for the complete area covered by the survey is also given for comparison. The differences between the capped and uncapped biomasses are evident from Figure 8, with the greatest difference for sardine on account of not only the capping effect but also attenuation at high densities, which occurs frequently. Table App.2 gives the relative variance–covariance matrix for the revised biomass series for the sardine November spawner biomass survey covering the area used in the assessments. Similar matrices have been produced for the remaining surveys (results not shown).

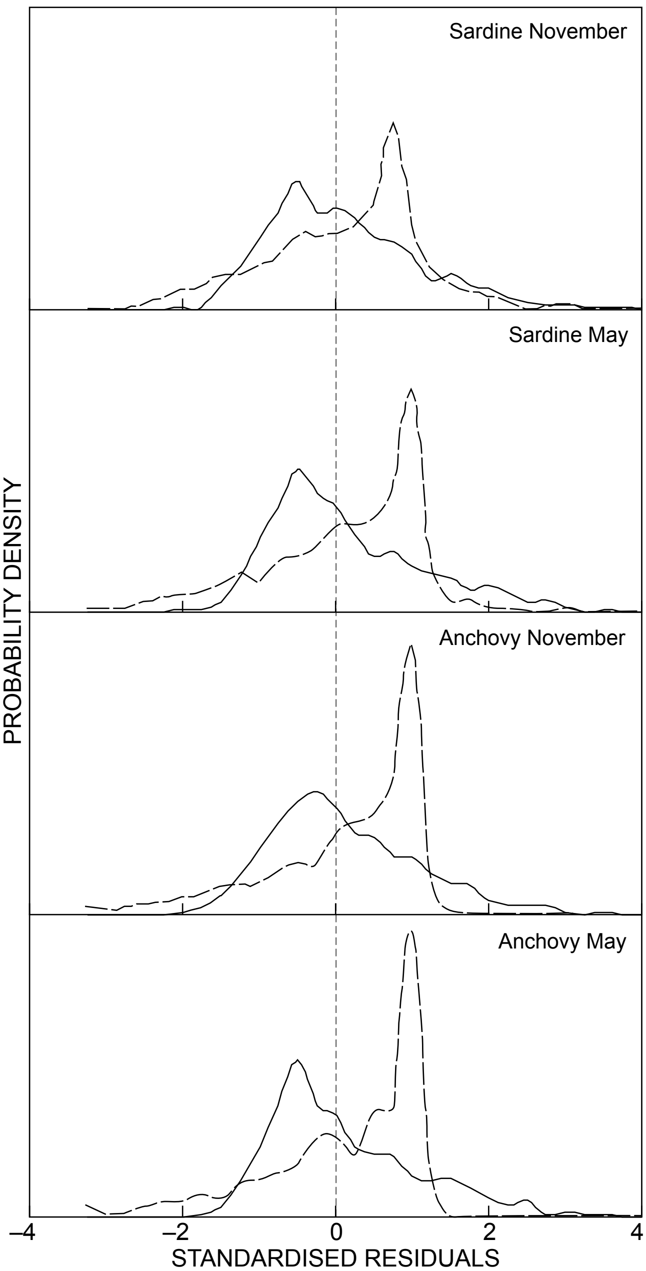

Figure 7: Probability density functions for the standardised residuals from the regression of capped data against uncapped data (Equation (2)). Pdfs are given for the case of fitting to the logit transform of the slope (solid lines) and the case of fitting directly to the slope (without transformation, dotted lines)

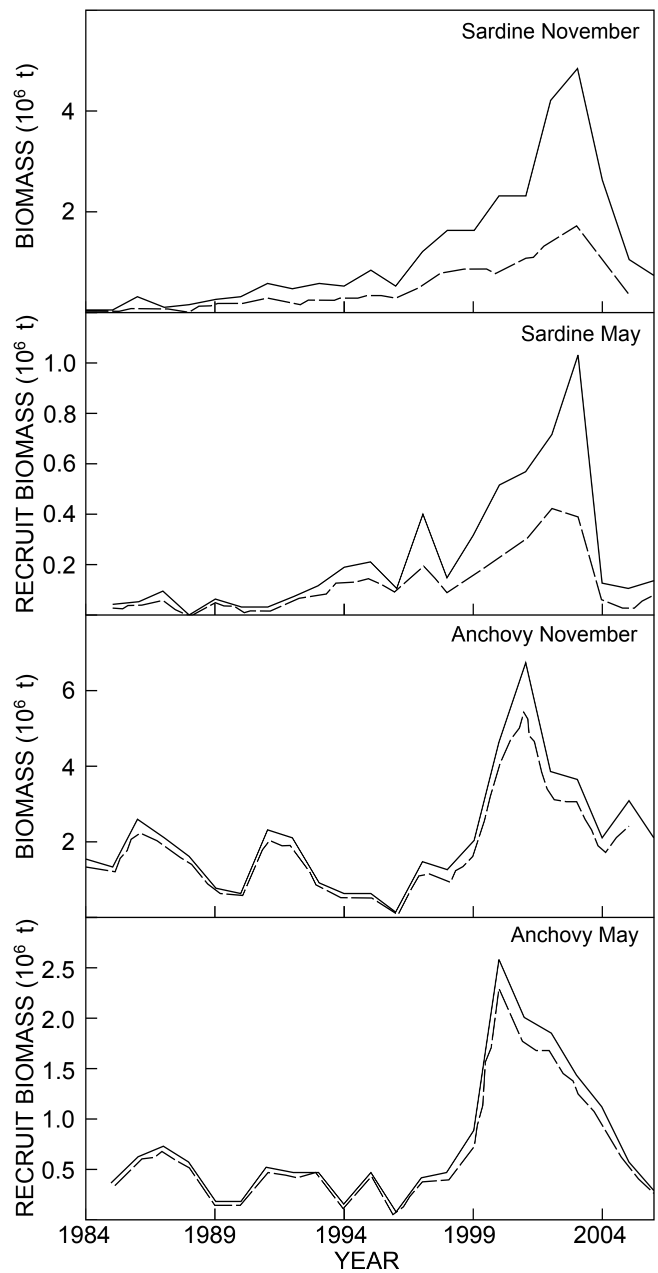

Figure 8: The capped (no attenuation for sardine) annual biomass (dotted lines) and uncapped (with attenuation for sardine) annual biomass series (solid lines) for the complete area covered by the survey. Uncapped values prior to 1998 are based upon the calibration adjustment relationships developed in this paper

Conclusion

This paper has detailed the method used to refine the survey biomass series for the South African sardine and anchovy resources. The updated series has been revised to take into account the effect of receiver saturation from the old SIMRAD EK400 echosounder as well as the effect of attenuation in dense sardine schools. Although there have been several attempts to estimate attenuation in dense schools (Toresen 1991, Zhao and Ona 2003), to our knowledge, corrections for this effect have seldom been made routinely. Similarly, the correction for changes in receiver saturation between different echosounders has not yet been documented elsewhere (see Coetzee *et al*. 2008 for further details).

The task required calculations to be carried out at an interval level rather than a stratum or even transect level.

The effect of both the capping and attenuation occurs at a school level and could not be appropriately averaged over a transect or stratum. The interval level constituted the smallest integration unit available over the entire time-series and was thus that used for analyses. Working at an interval level did, however, result in a considerable number of data points for which the observed capped and uncapped densities were equal. A mixture model was therefore required to be able to deal with these cases in which the observed slope was unity. Using a logit transformation on slope when observed slope was less than unity gave residuals that were quasi-normal (by comparison to those obtained without transformation), and also ensured that resampled slopes generated in the bootstrap variance estimation were realistically bounded between 0 and 1.

A single model, consisting of three straight lines followed by a constant, was chosen to model the probability that slope was 1 for both the November and May surveys, and for both sardine and anchovy. Two models of lslope in which observed slope was less than unity were chosen: one resembling a Beverton-Holt shape for the May surveys, and a separate one for the November surveys in which the lslope resembled a Beverton-Holt shape at low densities, while at high densities was kept constant. Although the whole process followed from regression to calibration adjustment should ideally be simulation tested, particularly because error structures are not preserved when inverting the capped vs uncapped relationships to obtain Equation (4), this is beyond the scope of this paper. Nevertheless, some sensitivity to the choice of model was tested for the sardine May survey. The BH-adjusted type model estimating the transition point u_1 and the BH-adjusted type model with u_1 fixed at 700 g m^{-2} and 900 g m^{-2} were used. The calibration adjustment exercise resulted in <3% difference in any one annual total biomass in these sensitivity tests to those obtained using the BH type model.

The CV reported with the total annual observed biomass per stratum takes inter-transect variability into account, while the calibrated CVs also account for error related to the calibration adjustment exercise and for error in the parameter estimates.

These refined survey biomass series for the South African sardine and anchovy will contribute to more accurate assessments of these resources, which ultimately should improve management of the South African pelagic fisheries.

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Appendix 1: Annual Biomass Series

Table App.1.1: The annual capped and uncapped with attenuation biomass (with CV) series for the November sardine spawner biomass survey, covering the area west of Port Alfred only. This is the survey series used in the assessment of the sardine resource. Cases in which the calibration adjustment factors have been applied are shown in bold. The contribution of each source of error to the CV of such calibration adjusted estimates is given, with $CV_{cal}(B_y)$ approximated (as CV_{cal} is only calculated by stratum) by solving Equation (13) using $CV_y^{tot}(B_y)$ in place of $CV_{y,s}^{tot}$ and $CV^{samp}(B_y)$ in place of $CV_{avg}^{samp}(\bar{u}_{y,s})$. The notation for the various contributions to the CV of the calibration adjusted estimates is evident from Equations (10)–(17). The comparative uncapped with attenuation biomass (with CV) for the complete area covered by the November sardine spawner biomass survey is also given

Year	Survey area used in the assessment								Complete area covered by survey	
	Capped, no attenuation		Uncapped with attenuation						Uncapped with attenuation	
	Biomass (t)	CV	Biomass (t)	CV_{avg}^{samp}	CV_{cal}	CV^{tot}	$\hat{CV}$	CV	Biomass (t)	CV
1984	40 062	0.958	**48 378**	**0.972**	**0.396**	**1.118**	**0.019**	**1.118**	**48 378**	**1.118**
1985	40 703	0.445	**45 013**	**0.449**	**0.218**	**0.509**	**0.008**	**0.509**	**45 013**	**0.509**
1986	127 576	0.456	**299 797**	**0.696**	**0.396**	**0.847**	**0.035**	**0.848**	**299 797**	**0.848**
1987	86 906	0.341	**111 285**	**0.402**	**0.449**	**0.629**	**0.028**	**0.630**	**111 285**	**0.630**
1988	68 269	0.515	**134 362**	**0.715**	**0.495**	**0.939**	**0.136**	**0.957**	**134 362**	**0.957**
1989	191 178	0.188	**256 655**	**0.225**	**0.146**	**0.270**	**0.040**	**0.274**	**256 655**	**0.274**
1990	216 420	0.265	**289 876**	**0.276**	**0.208**	**0.350**	**0.035**	**0.352**	**289 876**	**0.352**
1991	328 666	0.206	**597 858**	**0.308**	**0.233**	**0.393**	**0.036**	**0.395**	**597 858**	**0.395**
1992	220 527	0.332	**494 157**	**0.488**	**0.393**	**0.656**	**0.039**	**0.658**	**494 157**	**0.658**
1993	264 801	0.269	**560 019**	**0.316**	**0.265**	**0.421**	**0.068**	**0.427**	**560 019**	**0.427**
1994	334 125	0.261	**518 354**	**0.280**	**0.221**	**0.362**	**0.070**	**0.370**	**518 354**	**0.370**
1995	389 620	0.325	**843 944**	**0.515**	**0.435**	**0.710**	**0.050**	**0.713**	**843 944**	**0.713**
1996	300 606	0.223	**529 456**	**0.359**	**0.270**	**0.459**	**0.096**	**0.471**	**529 456**	**0.471**
1997	561 777	0.210	**1 224 632**	**0.244**	**0.205**	**0.323**	**0.062**	**0.329**	**1 224 632**	**0.329**
1998	843 078	0.206	1 607 328	0.251				0.251	1 607 328	0.251
1999	883 571	0.170	1 635 410	0.212				0.212	1 635 410	0.212
2000	855 402	0.360	2 292 380	0.500				0.500	2 292 380	0.500
2001	1 130 643	0.122	2 309 600	0.142				0.142	2 309 600	0.142
2002	1 443 847	0.182	4 206 250	0.227				0.227	4 206 250	0.227
2003	1 439 415	0.174	3 564 171	0.197				0.197	4 827 375	0.186
2004	1 078 175	0.271	2 615 715	0.334				0.334	2 628 700	0.332
2005	394 033	0.295	1 048 991	0.300				0.300	1 073 347	0.294
2006	Data unavailable		712 553	0.346				0.346	723 990	0.341

Table App.1.2: As for Table App.1.1, but for the May sardine recruit survey. The survey area west of Cape Infanta only is used in the assessment of the sardine resource

Year	Survey area used in the assessment								Complete area covered by survey	
	Capped, no attenuation		Uncapped with attenuation						Uncapped with attenuation	
	Biomass (t)	CV	Biomass (t)	CV_{avg}^{samp}	CV_{cal}	CV^{tot}	$\hat{CV}$	CV	Biomass (t)	CV
1985	31 023	0.342	**38 265**	**0.398**	**0.413**	**0.596**	**0.017**	**0.596**	**38 265**	**0.596**
1986	36 852	0.310	**50 073**	**0.347**	**0.455**	**0.593**	**0.031**	**0.594**	**50 073**	**0.594**
1987	58 872	0.338	**98 643**	**0.413**	**0.383**	**0.585**	**0.108**	**0.598**	**98 643**	**0.598**
1988	4 921	0.371	**5 223**	**0.374**	**0.138**	**0.402**	**0.005**	**0.402**	**5 223**	**0.402**
1989	51 773	0.285	**66 081**	**0.359**	**0.471**	**0.615**	**0.023**	**0.616**	**66 081**	**0.616**
1990	24 455	0.538	**31 208**	**0.605**	**0.578**	**0.906**	**0.020**	**0.907**	**31 208**	**0.907**
1991	24 299	0.229	**26 665**	**0.237**	**0.139**	**0.276**	**0.006**	**0.276**	**26 665**	**0.276**
1992	66 547	0.253	**74 822**	**0.263**	**0.185**	**0.325**	**0.008**	**0.325**	**74 822**	**0.325**
1993	81 075	0.238	**114 956**	**0.231**	**0.263**	**0.355**	**0.044**	**0.358**	**114 956**	**0.358**
1994	59 746	0.231	**72 462**	**0.251**	**0.177**	**0.311**	**0.020**	**0.311**	**187 982**	**0.360**
1995	143 594	0.191	**205 149**	**0.214**	**0.263**	**0.343**	**0.037**	**0.345**	**212 024**	**0.334**
1996	61 343	0.270	**73 612**	**0.295**	**0.215**	**0.370**	**0.016**	**0.370**	**104 635**	**0.299**
1997	205 047	0.169	**396 718**	**0.278**	**0.271**	**0.395**	**0.132**	**0.420**	**396 718**	**0.420**
1998	87 010	0.364	134 907	0.354				0.354	142 608	0.337
1999	122 444	0.285	235 720	0.378				0.378	312 015	0.319
2000	167 216	0.283	299 473	0.359				0.359	515 725	0.282
2001	309 350	0.212	573 427	0.285				0.285	573 435	0.285
2002	392 253	0.171	616 331	0.183				0.183	716 249	0.194
2003	318 823	0.188	600 667	0.217				0.217	1 030 977	0.251
2004	32 737	0.349	40 419	0.324				0.324	129 398	0.482
2005	11 358	0.291	17 245	0.337				0.337	105 048	0.492
2006	42 109	0.375	50 394	0.379				0.379	140 714	0.330

Table App.1.3: As for Table App.1.1, but for the November anchovy spawner biomass survey. The survey area west of Port Alfred only is used in the assessment of the anchovy resource

Year	Survey area used in the assessment								Complete area covered by survey	
	Capped		Uncapped						Uncapped	
	Biomass (t)	CV	Biomass (t)	CV_{avg}^{samp}	CV_{cal}	CV^{tot}	$\hat{CV}$	CV	Biomass (t)	CV
1984	1 428 571	0.249	**1 553 813**	**0.254**	**0.119**	**0.282**	**0.008**	**0.282**	**1 553 813**	**0.282**
1985	1 261 685	0.177	**1 366 294**	**0.183**	**0.102**	**0.210**	**0.007**	**0.211**	**1 366 294**	**0.211**
1986	2 312 075	0.146	**2 568 625**	**0.148**	**0.085**	**0.171**	**0.014**	**0.172**	**2 568 625**	**0.172**
1987	1 931 454	0.130	**2 108 771**	**0.132**	**0.084**	**0.157**	**0.008**	**0.157**	**2 108 771**	**0.157**
1988	1 472 816	0.201	**1 607 060**	**0.204**	**0.086**	**0.222**	**0.008**	**0.222**	**1 607 060**	**0.222**
1989	695 811	0.141	**751 529**	**0.143**	**0.086**	**0.167**	**0.007**	**0.167**	**751 529**	**0.167**
1990	609 071	0.166	**651 711**	**0.167**	**0.074**	**0.183**	**0.005**	**0.183**	**651 711**	**0.183**
1991	2 130 007	0.136	**2 327 834**	**0.140**	**0.074**	**0.158**	**0.009**	**0.159**	**2 327 834**	**0.159**
1992	1 904 181	0.133	**2 088 025**	**0.140**	**0.078**	**0.160**	**0.011**	**0.161**	**2 088 025**	**0.161**
1993	848 964	0.187	**916 359**	**0.190**	**0.085**	**0.209**	**0.006**	**0.209**	**916 359**	**0.209**
1994	573 741	0.136	**617 276**	**0.136**	**0.081**	**0.159**	**0.006**	**0.159**	**617 276**	**0.159**
1995	552 323	0.191	**601 271**	**0.192**	**0.098**	**0.217**	**0.008**	**0.217**	**601 271**	**0.217**
1996	152 547	0.389	**162 048**	**0.391**	**0.112**	**0.410**	**0.004**	**0.410**	**162 048**	**0.410**
1997	1 248 483	0.261	1 482 633	0.267				0.267	1 482 633	0.267
1998	970 109	0.209	1 229 132	0.217				0.217	1 229 132	0.217
1999	1 723 504	0.149	2 052 156	0.156				0.156	2 052 156	0.156
2000	4 107 722	0.119	4 653 779	0.125				0.125	4 653 779	0.125
2001	5 425 611	0.112	6 720 287	0.107				0.107	6 720 287	0.107
2002	3 152 741	0.144	3 867 649	0.154				0.154	3 867 649	0.154
2003	3 025 983	0.260	3 563 232	0.236				0.236	3 628 120	0.232
2004	1 680 797	0.133	2 044 615	0.131				0.131	2 111 674	0.130
2005	2 439 135	0.136	3 077 001	0.144				0.144	3 078 957	0.144
2006	Data unavailable		2 106 273	0.136				0.136	2 126 566	0.135

Table App.1.4: As for Table App.1.1, but for the May anchovy recruit survey. The survey area west of Cape Infanta only is used in the assessment of the anchovy resource

Year	Survey area used in the assessment								Complete area covered by survey	
	Capped, no attenuation		Uncapped						Uncapped	
	Biomass (t)	CV	Biomass (t)	CV_{avg}^{samp}	CV_{cal}	CV^{tot}	$\hat{CV}$	CV	Biomass (t)	CV
1985	351 192	0.249	**368 623**	**0.250**	**0.076**	**0.263**	**0.004**	**0.263**	**368 623**	**0.263**
1986	590 481	0.170	**621 089**	**0.171**	**0.062**	**0.183**	**0.004**	**0.183**	**621 089**	**0.183**
1987	685 368	0.154	**721 578**	**0.155**	**0.050**	**0.163**	**0.004**	**0.163**	**721 578**	**0.163**
1988	537 073	0.154	**563 107**	**0.155**	**0.049**	**0.162**	**0.004**	**0.163**	**563 107**	**0.163**
1989	166 411	0.188	**173 349**	**0.189**	**0.067**	**0.201**	**0.003**	**0.201**	**173 349**	**0.201**
1990	163 346	0.216	**170 083**	**0.216**	**0.062**	**0.225**	**0.003**	**0.225**	**170 083**	**0.225**
1991	503 787	0.139	**528 177**	**0.140**	**0.050**	**0.148**	**0.004**	**0.149**	**528 177**	**0.149**
1992	439 497	0.157	**458 455**	**0.157**	**0.051**	**0.166**	**0.003**	**0.166**	**458 455**	**0.166**
1993	459 671	0.246	**481 108**	**0.248**	**0.071**	**0.259**	**0.004**	**0.259**	**481 108**	**0.259**
1994	139 290	0.170	**145 336**	**0.170**	**0.058**	**0.180**	**0.004**	**0.180**	**145 341**	**0.180**
1995	373 796	0.167	**392 016**	**0.168**	**0.059**	**0.178**	**0.004**	**0.178**	**461 878**	**0.173**
1996	72 223	0.212	**74 842**	**0.213**	**0.061**	**0.222**	**0.003**	**0.222**	**90 083**	**0.213**
1997	385 829	0.174	**404 620**	**0.174**	**0.061**	**0.185**	**0.004**	**0.185**	**404 620**	**0.185**
1998	390 116	0.149	453 210	0.149				0.149	466 994	0.147
1999	695 510	0.139	826 090	0.158				0.158	878 682	0.155
2000	2 305 278	0.179	2 553 502	0.170				0.170	2 578 745	0.168
2001	1 753 811	0.140	1 998 427	0.134				0.134	2 002 963	0.133
2002	1 405 886	0.118	1 560 101	0.115				0.115	1 855 123	0.118
2003	1 290 825	0.205	1 434 900	0.190				0.190	1 436 165	0.189
2004	943 521	0.223	1 071 419	0.223				0.223	1 113 280	0.216
2005	528 378	0.277	560 518	0.269				0.269	564 858	0.267
2006	236 941	0.158	275 797	0.182				0.182	297 906	0.171

Appendix 2: Variance–Covariance Matrix

Table App.2: The relative variance–covariance matrix for the revised uncapped, with attenuation, biomass series from the November sardine spawner biomass surveys, in which the numbers shown correspond to the square roots of the actual values for better discrimination. Hence, the diagonal elements are identical to $\sqrt{CV}$ of Table App.1.1

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1984	1.057	0.110	0.140	0.150	0.218	0.164	0.159	0.156	0.152	0.184	0.187	0.168	0.201	0.179									
1985	0.110	0.713	0.116	0.119	0.173	0.130	0.127	0.126	0.124	0.147	0.148	0.135	0.160	0.144									
1986	0.140	0.116	0.921	0.161	0.241	0.178	0.170	0.183	0.190	0.210	0.203	0.199	0.221	0.206									
1987	0.150	0.119	0.161	0.794	0.247	0.183	0.177	0.176	0.173	0.208	0.210	0.190	0.227	0.202									
1988	0.218	0.173	0.241	0.247	0.978	0.271	0.261	0.260	0.258	0.309	0.312	0.283	0.337	0.301									
1989	0.164	0.130	0.178	0.183	0.271	0.523	0.194	0.193	0.190	0.228	0.230	0.209	0.249	0.222									
1990	0.159	0.127	0.170	0.177	0.261	0.194	0.593	0.186	0.183	0.220	0.222	0.201	0.240	0.214									
1991	0.156	0.126	0.183	0.176	0.260	0.193	0.186	0.628	0.192	0.222	0.221	0.206	0.239	0.217									
1992	0.152	0.124	0.190	0.173	0.258	0.190	0.183	0.192	0.811	0.222	0.218	0.208	0.237	0.217									
1993	0.184	0.147	0.210	0.208	0.309	0.228	0.220	0.222	0.222	0.654	0.262	0.241	0.283	0.255									
1994	0.187	0.148	0.203	0.210	0.312	0.230	0.222	0.221	0.218	0.262	0.608	0.239	0.286	0.255									
1995	0.168	0.135	0.199	0.190	0.283	0.209	0.201	0.206	0.208	0.241	0.239	0.844	0.259	0.235									
1996	0.201	0.160	0.221	0.227	0.337	0.249	0.240	0.239	0.237	0.283	0.286	0.259	0.687	0.276									
1997	0.179	0.144	0.206	0.202	0.301	0.222	0.214	0.217	0.217	0.255	0.255	0.235	0.276	0.574									
1998															0.501								
1999																0.460							
2000																	0.707						
2001																		0.377					
2002																			0.476				
2003																				0.443			
2004																					0.578		
2005																						0.548	
2006																							0.589