A Review of World Sardine Catch Patterns: What can be said about the Likely Duration of the Current Peak in South African Sardine Fishery

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Abstract

The question of how long the current peak in South African sardine catch will extend is posed. Historic sardine catch series throughout the world are considered and two models are fitted to these series to establish their reliability for predicting future trends in catches. The authors find little basis to draw conclusions for the South African resource based on trends elsewhere. More dependable inferences may be forthcoming from the South African catch series itself, analyses of which suggest that catches may remain high (above some 200 000 tons) until about 2007, but this inference should not be considered particularly reliable.

Introduction

The South African sardine resource has increased strongly in recent years. The last observed peak in abundance occurred during the 1960s, and was followed by a lengthy period of low abundance. The current high recruitment levels have prompted questions as to how long such a peak in sardine abundance might be expected to last, as well as how frequently such peaks might occur. Given that long-term rights for the South African pelagic fishery will be awarded later this year, such questions are of particular interest to industries considering investment alternatives.

Schwartzlose *et al*. (1999) reviewed historic catches and in some cases biomass estimates of sardine populations throughout the world, including sardine found in the north-west, north-east and south-east Pacific and in the south-east Atlantic. No future forecasting was attempted nor were any inferences drawn from the data regarding how long peaks in abundance might last.

Klyashtorin (2001) used spectral analysis based on climate indices to estimate the periodicity in the historic commercial catch time series of a number of species and stocks, including European, South African, Peruvian, Japanese and Californian sardine. He developed a stochastic model to forecast the long-term fluctuations of catches, based on a 55 to 65 year periodicity deduced from the spectral analysis.

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In this paper we consider historic patterns of sardine catches in various parts of the world to see if any inferences can be drawn from them regarding the catch series for the South African sardine resource. In particular, we consider whether the duration of the current peak in South African sardine recruitment can be reliably predicted.

Methods

Prior to considering any quantitative models, we compared the historic catch series in Schwartzlose *et al*. (1999) to determine if any patterns in the timing and duration of peaks were evident. Subsequently two models were applied as elaborated below.

Klyashtorin's (2001) deterministic model for the prediction of catch dynamics ($C(t)$) is a multiple cyclic trend with m periods T_i, $i=1,\ldots,m$, unknown amplitudes, B_i and D_i, and unknown static shift constant, G:

$$C(t)=\sum_{i=1}^{m}\left(B_i\sin(\theta_i(t))+D_i\cos(\theta_i(t))\right)+G\text{ , where }\theta_i(t)=2\pi(t-t_0)/T_i\,. \tag{1}$$

We attempted to fit this model, assuming the amplitudes B_i and D_i were the same for all i, thereby estimating four parameters, to catch data in Schwartzlose *et al*. (1999) by minimising a sum of squared differences between observed and model-estimated values.

In addition, we attempted to fit a new model consisting of a constant over time to which normally distributed periodic peaks were added. Given m normal distributions with equal periods P and variance σ^2, and the earliest distribution mean occurring at time T years, the model to fit catch trends is given by:

$$C(t)=\sum_{i=1}^{m}A\times N\left(T+(i-1)P,\sigma^2\right)+G\,, \tag{2}$$

where A denotes the amplitude of the peak in the normal distributions and G denotes the constant catch evident for years well separated from peaks. This model was fitted to catch data in Schwartzlose *et al*. (1999) by minimising the sum of squared residuals as above, and was also later fitted by minimising a lognormal likelihood function. In an attempt to reduce some of the correlation between the residuals for the fit, first-, second- and finally third-order autoregression was also taken into account in the model, using a lognormal likelihood function.

Results

Figure 1 shows the scaled historic catch series from some of the larger areas considered by Schwartzlose *et al*. (1999). The first notable feature is that the South African and Namibian catch series peaked during the 1960s, at a time when all the other catch series were in a trough. Thus, even if the peaks in catches in some of the areas could be considered to be synchronous, they do not coincide with the peaks observed in southern Africa and can therefore not be used to predict the time of occurrence of peaks in this region. Secondly, if one considers the duration of the peak to constitute the period while the catch is above 50%

of the recorded maximum value, then historically the peaks in catches have ranged from 7 to 14 years (Table 1).

Figure 2 shows the fit of Klyashtorin's deterministic model to the South African sardine catch data in Schwartzlose *et al*. (1999), and to an extended series including more recent data (Cunningham and Butterworth (2004)). The period estimated by this model is 45 years, much shorter than that estimated by Klyashtorin when using data from a number of sources. When more recent catch data are included, the catch series estimated by the model does not show much change. The model fit, particularly to the observed peaks in the catch data, is unsatisfactory with the model estimated catches appearing to 'average' over years of sharp increase or decrease in actual catch.

Figure 3 shows some further fits of Klyashtorin's deterministic model to catch data in Schwartzlose *et al*. (1999). Once again the model fit to some of the observed peaks in catch data is unsatisfactory. In some cases, for example the north-west and north-east Pacific, the model suggests negative catches during troughs. The estimated periods between consecutive peaks ranged between 42 and 71 years – a much wider range than that estimated by Klyashtorin's stochastic model as reported in Klyashtorin (2001). This stochastic model consisted of the deterministic model given in equation (1) above, together with an autoregressive Box-Jenkins model. Note, however, that in some cases (e.g. Namibia) the period cannot be estimated precisely due to the absence of a second increase in the recorded catch series.

Given the different periodicity estimated for different sets of data, and the variability in the duration of peaks, it would seem unwise to use such a model together with data from other sardine populations to predict the duration of and/or period between peaks in the South African sardine catch.

The new model introduced in this paper consisting of a constant with added normal distributions was able to reflect the observed peak in the historic catch series more closely (e.g., Figure 4 for South Africa). The peaks in the catches estimated by the model were much narrower and higher, with the model predicting a peak centred around 2002, close to what has recently been observed.

When a lognormal likelihood was minimised to fit the model rather than use the sum of squares method, the estimated peak in the catch deceased and widened as a result of the relatively lower influence then associated with large catch values (compare Figures 4 and 5). Only the third-order autoregressive model was able to accurately reflect the peak in catches in the early 1960s (Figure 5). Although some small improvement (e.g. during the 1960s) in the randomness of the residuals was obtained by the inclusion of first-, second- and third-order autoregression, the residuals after third-order autoregression was included were still not random (Figure 6).

When the new model was fit to the South African sardine catch series in Schwartzlose *et al*. (1999) together with more recent data (Cunningham and Butterworth (2004)), the estimated series predicts the second peak to occur slightly later (i.e. a slightly longer inter-peak period) (Figure 7).

Discussion

Models such as those considered in this paper assume a fairly low frequency longer-term variation in the environment, with resource abundance being the dominant factor determining catches, and furthermore that such catches have a limited impact on the abundance of the resource. In reality, observed catches will have been determined by delays in investment (growth of the fleet) as the industries in the countries involved in the fishery developed, followed by the effects of regulations such as TACs, and these factors are not of such a nature as to necessarily lead to random deviations about a deterministic model. Due to the impact of such factors on the initial recorded peak (and in many cases only one complete peak in historic catch has been recorded), using that peak to extrapolate to provide features of the subsequent peak in the series is risky.

Given the lack of faith placed in the results of the models used in this paper and the lack of similarity between the historic South African catch series compared to the catch series from other parts of the world, the authors suggest that the most “reliable” information to use in predicting the duration of the current peak in South African sardine catch series is earlier data from the same fishery. The previous recorded peak in South African sardine catch lasted 7 years (if ‘peak’ is defined as occurring above 50% of recorded maximum catch). The historically recorded maximum in South African sardine catch was 410 200 tons. The catch in 2001 was near 50% of this value and exceeded it in 2002. On this basis, one might expect catches to remain “high” (above 200 000 tons) until about 2007, but the authors wish to emphasise that the level of reliability associated with such conclusions is extremely low, given the generally poor predictive power evident from the poor fits of the models considered in this paper and their limited *a priori* justification.

References

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Table 1. Estimated duration of peaks in historic observed catches (data in Schwartzlose et al. (1999)).

Area	Considering Total Peak Duration			Considering Peak Duration from 50% of Maximum Recorded Catch		
	Year of first noticeable increase	Year of last noticeable decrease	Duration	Year first above 50% of max	Year last above 50% of max	Duration
NW Pacific	1975	1995	21	1980	1992	13
California	1921	1952	32	1933	1945	13
Seasonal NW America	1921	1952	32	1933	1945	13
Gulf of California	1978	1991	14	1983	1989	7
Peru and Chile	1975	1996	22	1979	1992	14
Australia	1978	1996#	19	1987	1996#	10
South Africa	1956	1967	12	1959	1965	7
Namibia	1951	1980	30	1964	1970	7

This is the final year recorded in Schwartzlose *et al.* (1999) and may therefore not be an accurate reflection of the end of the peak.

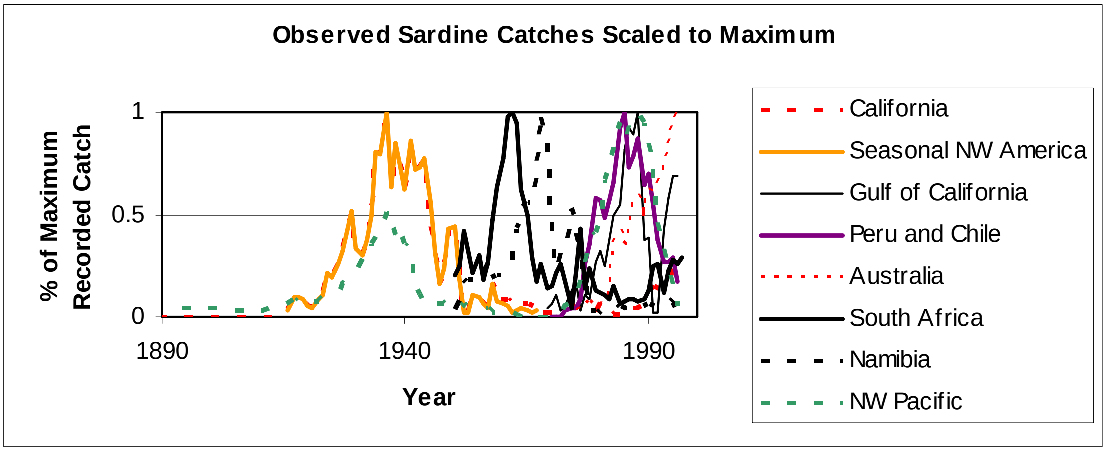


Figure 1. Sardine catch series (from Schwartzlose et al. (1999)) scaled to the maximum values observed.

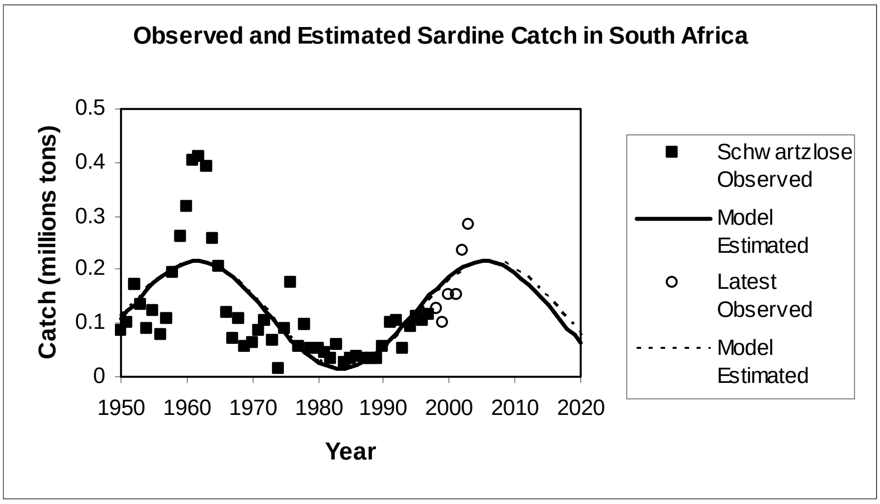


Figure 2. Observed South African sardine catch data (from Schwartzlose et al. (1999) and updated from Cunningham and Butterworth (2004)) together with the catches estimated using the deterministic version of Klyashtorin's (2001) model.

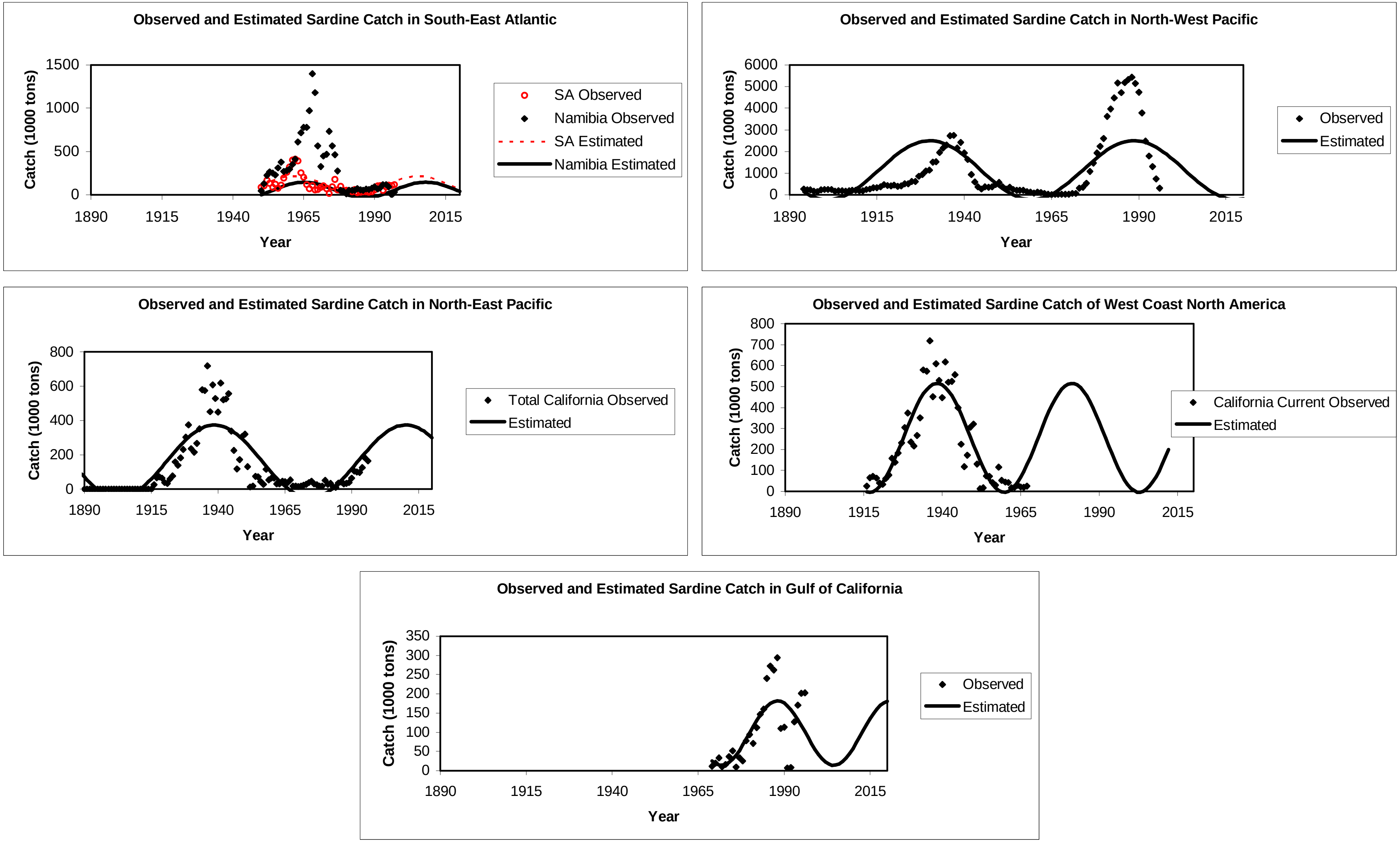


Figure 3. Observed sardine catch data (from Schwartzlose et al. (1999)) together with the catches estimated using the deterministic version of Klyashtorin's (2001) model.

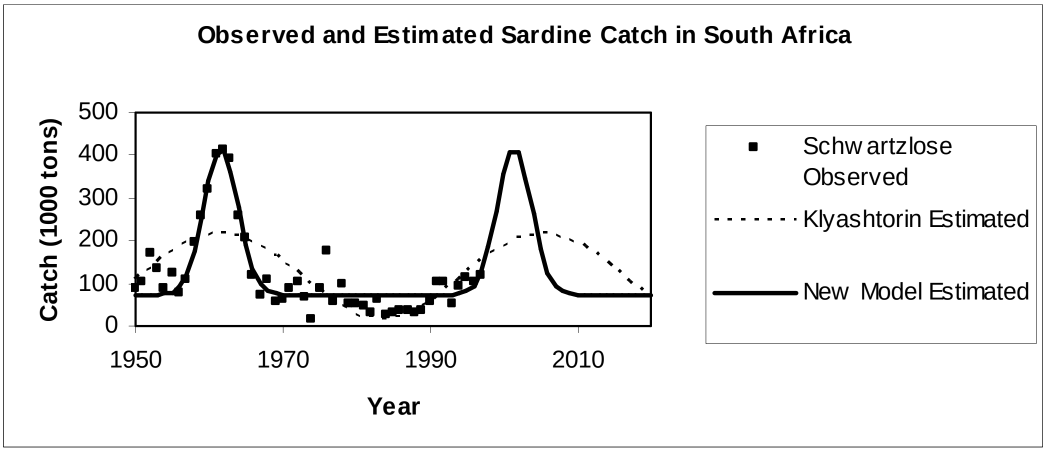


Figure 4. Observed South African sardine catch data (from Schwartzlose et al. (1999)) together with the catches estimated using the deterministic version of Klyashtorin's (2001) model and the new model developed in this paper. Both are fitted using a sum of squares objective function.

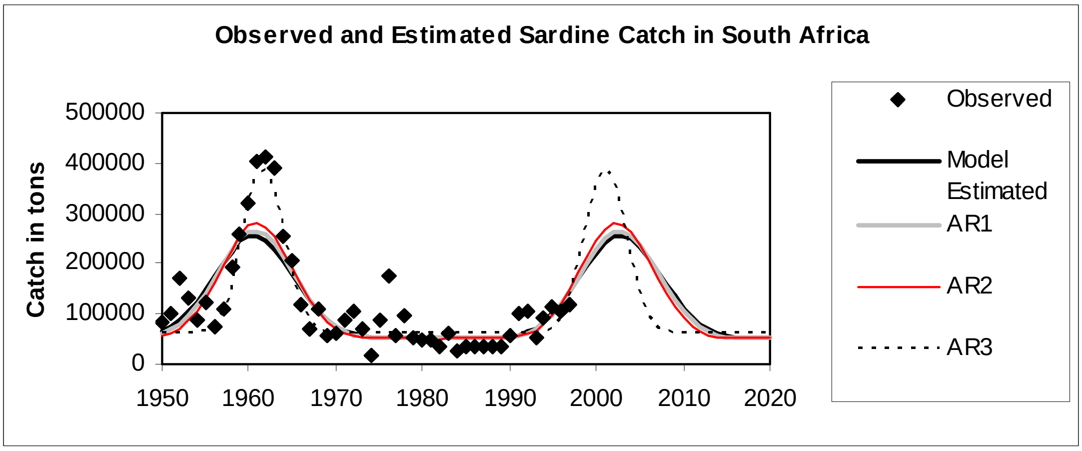


Figure 5. Observed South African sardine catch data (from Schwartzlose et al. (1999)) together with the catch series estimated by the new model developed in this paper, also taking account of first-order, second-order and third-order autoregression. The models shown here are fitted using a lognormal likelihood.

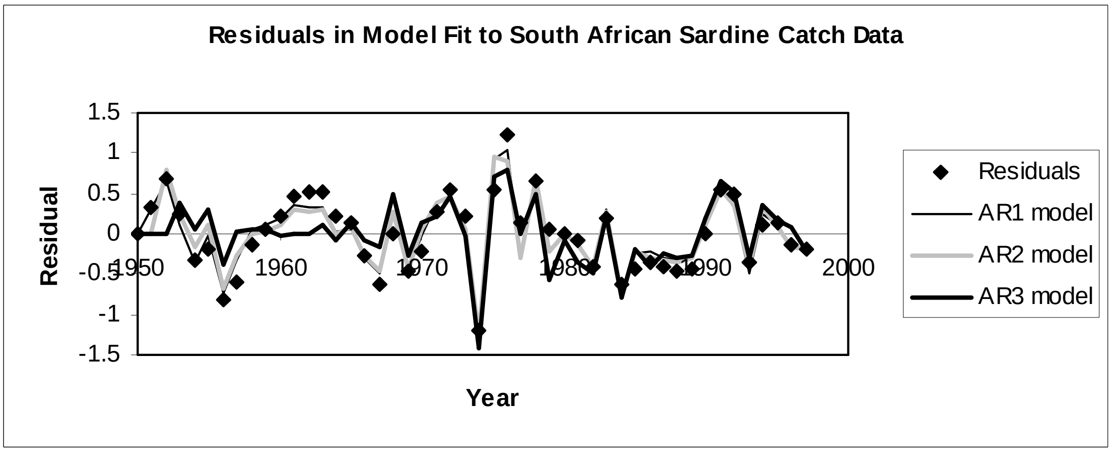
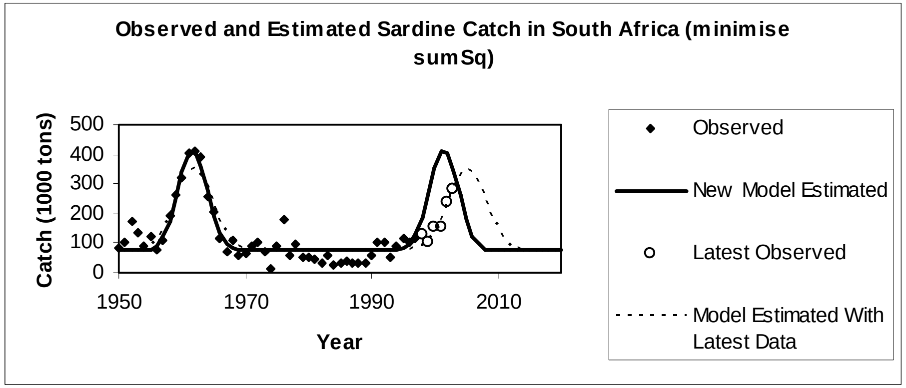


Figure 6. Residuals for the fits of the models of South African sardine catch data (from Schwartzlose et al. (1999)) shown in Figure 5 which use the new model with a lognormal likelihood and take account of first-, second- and third-order autoregression.



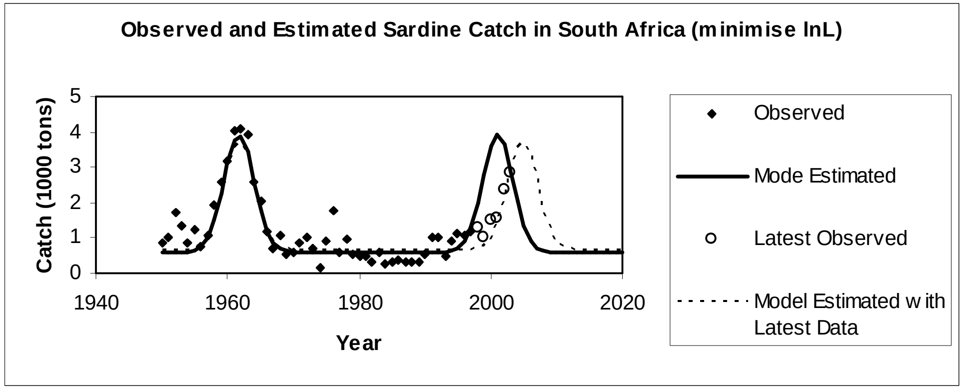


Figure 7. Observed South African sardine catch data (from Schwartzlose et al. (1999)) and updated from Cunningham and Butterworth (2004) together with the catch series estimated using the new model developed in this paper. The first figure shows the fits obtained using a sum of squares objective function, while the second figure shows the fits obtained using a lognormal likelihood and taking account of third-order autoregression.