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A note on the impact of accounting for age-determination error on the outcome of the statistical catch-at-age analysis for Antarctic minke whales

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ABSTRACT
The impact of allowing for ageing error when conducting assessments for Antarctic minke whales in Areas III-E, IV, V and V-W using statistical catch-at-age analysis is explored using sensitivity tests. The sensitivity tests explore three scenarios: (a) no ageing error, (b) ageing error is modelled as in previous base-models, and (c) ageing error is based on the results of the recent minke whale age-reading error experiment. Time-trajectories of total (1+) population size and recruitment are qualitatively the same, irrespective of how age-reading error is modelled. However, the analyses based on results of the recent age-reading error experiment did not lead to a positive definite hessian matrix. The reasons for this need to be understood and the results confirmed before final conclusions can be drawn.

KEYWORDS: CATCH-AT-AGE, MINKE WHALE, SOUTHERN HEMISPSHERE

INTRODUCTION

Two variants of catch-at-age analysis have been applied to data for the Antarctic minke whales in recent years. Mori and colleagues (e.g. Mori *et al*., 2007; Mori and Butterworth, 2008) have applied ADAPT-VPA while Punt and Polacheck (e.g. Punt and Polacheck (2005, 2006, 2007, 2008)) have applied statistical catch-at-age analysis. With a few exceptions, both of these techniques concluded that the population size of Antarctic minke whales increased from 1930 to the late 1970s, and declined thereafter.

The conclusion that an increase in abundance occurred before 1970 is inferred from changes in the age-structure of the catches over time, along with trends in relative and absolute abundance [unlike most applications of catch-at-age analysis, the catches of minke whales have never been a large fraction of the population so changes in population sizes are due primarily to changes over time in recruitment]. In principle, spurious trends in abundance could be created if there is age-reading error, and the level of this error changed over time.

The statistical catch-at-age analysis of Punt and Polacheck can take age-reading error (both bias and imprecision) into account. However, until recently, there was no basis on which to specify the nature of any ageing error, and previous base-models have been based on the assumption that the age-estimates are unbiased, but subject to random age-reading error with a CV of 0.1 An age-reading error experiment was conducted recently in which a range of earplugs which were originally read during the early 1970s to the recent years were re-read. Kitakado and Punt (2010) applied variants of the model developed by Punt *et al*. (2008) to estimate the extent of ageing bias and random age-reading error and hence age-reading error matrices for three periods / readers using these data.

This paper explores the quantitative impact of including the age-reading error matrices estimated by Kitakado and Punt (2010) on the outcomes of the statistical catch-at-age analysis and, in particular, whether allowing for age-reading error leads to a change to inference of an increase in the abundance of Antarctic minke whales before 1970.

METHODS

The basic catch-at-age analysis

The data and basic method of analysis is identical to that used by Punt and Polacheck (2008). This analysis considers the years 1930/31 to 2003/04 (although catch data are only available from 1953/54 and catch-at-age data are only available from 1971/72).

The scenarios

Three scenarios are considered: (a) age-estimates are unbiased, but subject to random age-reading error with a CV of 0.1 [“reference case”], (b) age-estimates are essentially exact (modelled by assuming that the age-estimates are unbiased, but subject to random age-reading error with a CV of 0.0001) [“No ageing error”], and (c) age-estimates are subject to ageing-error based on the results of Kitakado and Punt (2010) [“with new age-matrices”].

Kitakado and Punt (2010) estimated age-reading error matrices for three readers: Misaki, Kato, and Zenitani. The third scenario is conducted under the assumption that the age-reading error matrix for each reader is time-invariant, and that the age-reading error matrix estimated for Misaki is representative of age-reading error for the age-readers before 1980/81 when Kato began to read earplugs. Consequently, the age-reading error matrices are computed by year as follows:

Year	Reader
1971/72 – 1979/80	Misaki
1980/81 – 1990/91	Kato
1992/91 – 1992/93	Zenitani
1993/94	Kato
1994/95 – 2005/06	Zenitani

RESULTS AND DISCUSSION

Figure 1 compares the results of the analyses in terms of the time-trajectories of total (1+) population size and recruitment. The time-trajectories all exhibit the same patterns, although recruitment based on the Kitakado-Punt age-reading error matrices is more variable among years. For stock E, the largest difference in results occurs when age-reading error is ignored (dotted lines in the lower panels of Figure 1).

All of these analyses are based on the same data and all estimate the same number of parameters (1,050). The fit of the “with new age-matrices” analysis is poorer in likelihood terms than that of the analysis in which the age-estimates are assumed to be unbiased, but subject to random age-reading error with a CV of 0.1. It should be noted, however, that the likelihood function does not include the data from the age-reading experiment which would tend to support the “with new age-matrices” case. Moreover, the fit of the model for the “with new age-matrices” analysis is not obviously poor (Figure 2). The rate of natural mortality for the oldest (age 35+) animals is higher for the “with new age-matrix” analysis (0188yr^{-1} and 0.196yr^{-1} for the stocks W and E respectively) than for “reference case” analysis (0.118yr^{-1} for both stocks).

The results of this paper suggest that allowing for better estimates of age-reading error is unlikely to change the qualitative conclusion of an increase in population size for Antarctic minke whales from 1930 until approximately 1970. The analysis based on the Kitakado-Punt age-reading error matrices did not lead to a positive definite hessian matrix. Achievement of a positive definite hessian matrix has always proved fairly difficult for the statistical catch-at-age analysis owing to the large number of parameters, but it is unclear why this problem occurred in this case. This needs to be explored using future analyses[1]. It is prudent not to draw final conclusions regarding whether ageing error is highly consequential regarding trends in the abundance of Antarctic minke whales until (a) the reasons for the lack of a positive definite hessian matrix are identified, and (b) the final data are agreed by the SC.

Finally, the "with new age-matrices" are based on the assumptions that (a) Lockyer is an unbiased reader and (b) there is no value in using the data from the 1983 minke ageing workshop (IWC 1984) to refine the age-reading error matrices. The SC may wish to comment on these assumptions.

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[1] The model is fairly complicated, which combined with lack of time before the SC meeting, precluded conducting this exploration for this paper.

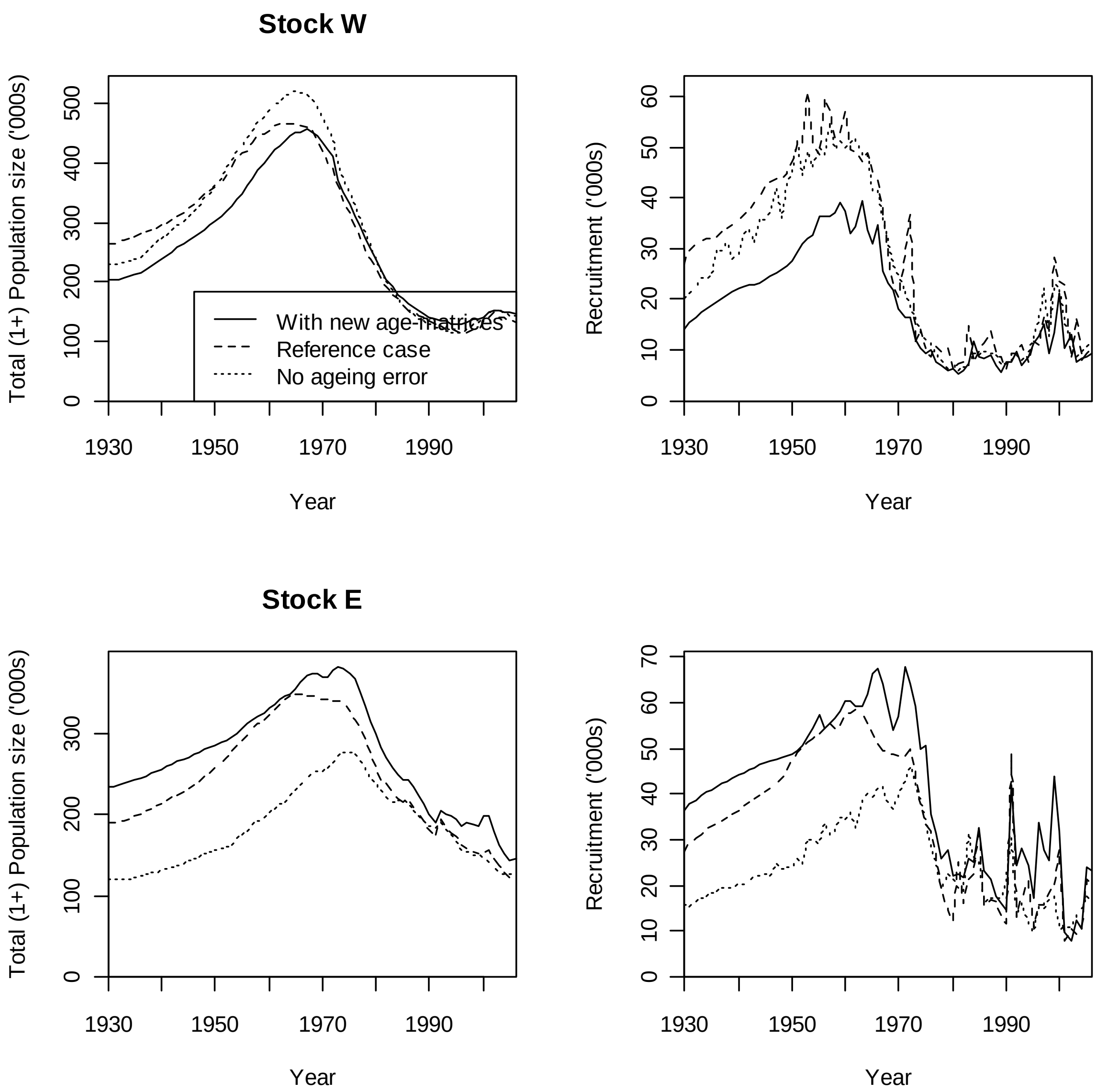

Figure 1. Time-trajectories of total (1+) population size and recruitment for three applications of the statistical catch-at-age analysis in which the assumptions regarding age-reading error are changed.

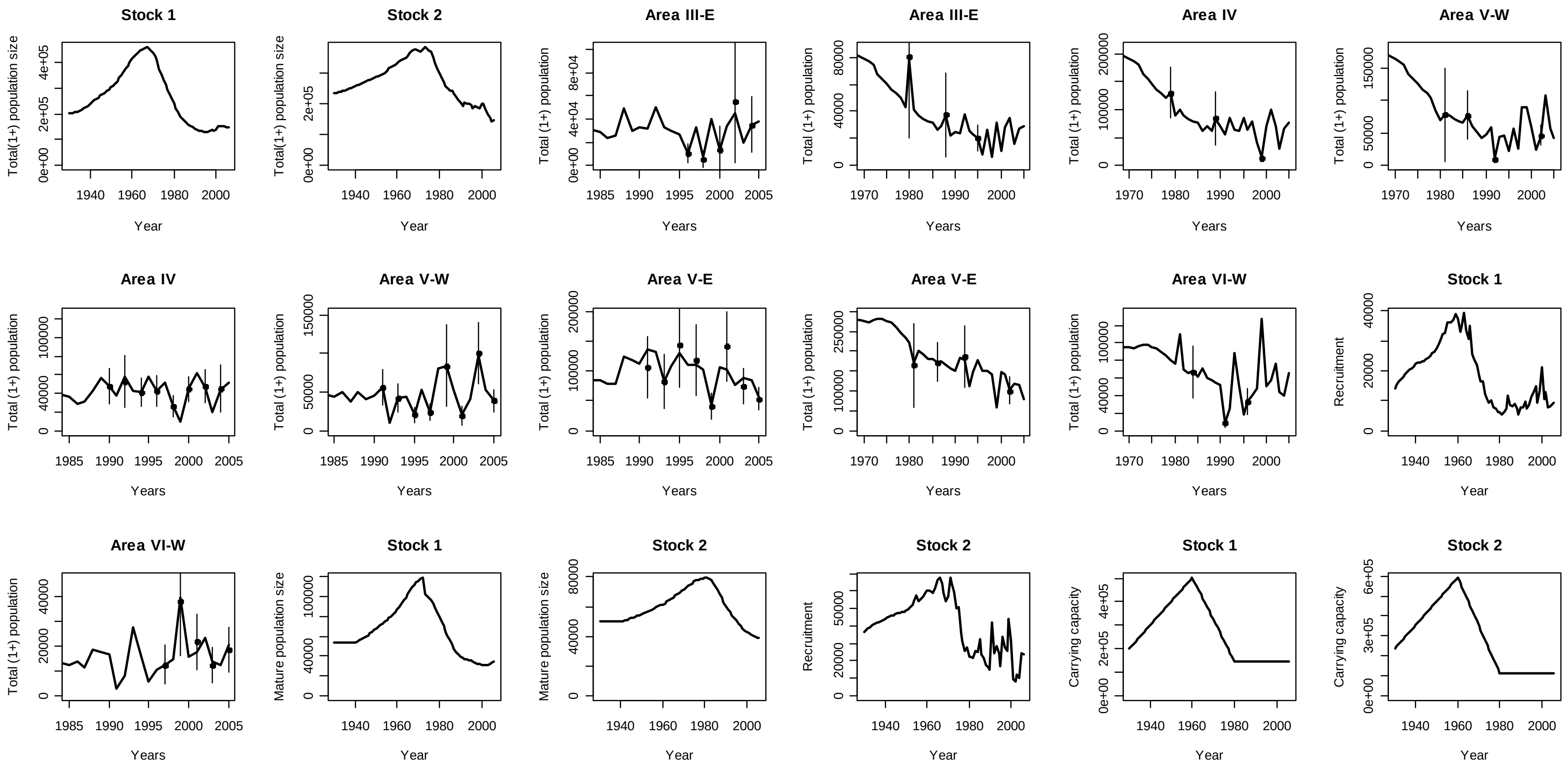

Figure 2. Detailed model outputs for the analysis based on the age-reading error matrices in Kitakado and Punt (2010).

Figure 2 Continued