Further Investigation of Whether Correlations amongst Data are Invalidating the Conclusion of a Statistically Significant Trend in Antarctic Minke Body Condition over Time

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ABSTRACT

A statistically significant decline in body condition in the Antarctic minke whale over the JARPA period was reported in Konishi *et al.* (2008). Subsequently, however, questions were raised in the IWC Scientific Committee as to whether the model used had adequately accounted for the data structure in JARPA (de la Mare, 2011), i.e. whether neglect of correlations in the data had led to negative bias in the confidence interval estimated for the decline. Earlier a jack-knife approach with year as the sampling unit was used to account for within-year correlations, and showed that while the confidence interval estimates reported originally had been negatively biased, the estimated decline remained statistically significant at the 5% level. This approach did not, however, take account of possible between-year correlations. This paper investigates the possibility that such correlations could have biased these interval estimates appreciably. The results show no sign of appreciable inter-annual auto-correlation, and indicate that the decline reported by Konishi *et al.* (2008) remains statistically significant at the 5% level. We suggest that his constitutes sufficient statistical evidence to confirm this significance, so that this matter might now be regarded as resolved by the Scientific Committee.

INTRODUCTION

Konishi *et al.* (2008) reported a decline of body condition in Antarctic minke whales over the 18 years of the JARPA period, having taken account of comments made on an earlier analysis at the JARPA review meeting (IWC, 2008). Subsequently, an SC member questioned whether adequate account had been taken in the regression analysis used of structure of JARPA data, suggesting that doing so could result in a different result with respect to the statistical significance of the trend reported (de la Mare, 2011). Walløe, (IWC, 2012) responded by reporting results for the jack-knife approach. This is a non-parametric approach which is applied with an enlarged sampling unit to account for the concerns about non-independence of data when treating an individual whale as the sampling unit, as had had been voiced by de la Mare. Naturally if this sampling unit is chosen to be larger than necessary to account for the lack of independence in the data, the resultant standard error estimate becomes positively biased. These jack-knife results confirmed that the estimated decline in blubber thickness remained statistically significant at the 5% level (IWC, 2012). Skaug (2012) also examined the blubber thickness trend using mixed-effect models, including an additional variance structure in accord with specific requests made by the EM Sub-Committee. The variance of the estimated trend became somewhat higher; however the point estimate of the trend changed little and remained significant at the 5% level.

de la Mare (2012) again suggested that spatial pseudo-replication in JARPA data needed to be considered. Some members considered, however, that his concern about non-independence amongst the data had already been addressed by Walløe's response above. However the jack-knife approach applied had used year (i.e. season) as the sampling unit. Therefore, while it subsumes auto-correlation at a within-year temporal scale, it would not have taken account

of possible auto-correlation over periods longer than one year. To address this, we have conducted an additional test to assess whether there is any such auto-correlation effect which might negatively bias the earlier jack-knife estimate of the variance of the decline in blubber thickness to any meaningful extent.

MATERIALS AND METHODS

Jack-knife method

Further to a jack-knife analysis of the form carried out by Walløe (IWC, 2012), we repeated such jack-knife computations with sampling units of two and three years to check for any appreciable increase in the standard error of the trend estimate that would suggest the presence of positive inter-year correlation effects sufficient to change conclusions concerning the statistical significance of the trend estimate.

The model used here is the best model (in terms of AIC) selected by Skaug (2012). It is written below in standard R notation where BLm is body length, 'DateNum' is the date within a year and 'YearNum' is the year number, with the trend parameter of interest being the slope associated with 'YearNum'. LongCat is a categorical variable coding for seven areas, the slope associated with 'DateNum' being variable over years and treated as a random effect, a random intercept is associated with 'Year', and a random intercept and slope (of 'DateNum') is associated with 'LongCat':

Lmer(BT11 ~ (DateNum|Year) + (DateNum|LongCat) + Diatom + LongDegE + YearNum + Latitude + BLm + Sex, data=blubber,REML=reml))

RESULTS

Jack-knife method

The annual trend estimates (in cm/yr) and associated jack-knife standard error estimates for each length of sampling unit (note that the 95% confidence intervals are based on the standard error estimates coupled to the assumption of distribution normality) are;

1 year: -0.0172 (-0.0211 to -0.0133 95%CI) SE=0.0020 *No. of sampling units*: 18
2 year: -0.0175 (-0.0209 to -0.0140 95%CI) SE=0.0018 *No. of sampling units*: 9
3 year: -0.0173 (-0.0244 to -0.0103 95%CI) SE=0.0036 *No. of sampling units*: 6

All these trend estimates are very close to that from the original model (Skaug 2012) and the 95% confidence intervals do not overlap 0 even with increasing length of the sampling unit. Note that some increase in the standard error would be expected as the length of the sampling unit is increased, as the effective extent of the period over which the regression slope is estimated is thereby reduced.

These results indicate that autocorrelation at the inter-year level is not introducing any bias that is of a level that would be of concern.

DISCUSSION

IWC report SC/59/Rep1 states.: "Finally, the Workshop agreed that the JARPA dataset provides a valuable resource to allow investigation of some aspects of the role of whales within the marine ecosystem. With appropriate analyses, this has the potential to make an important contribution to the Scientific Committee's work in this regard, as well as the work of other relevant bodies such as CCAMLR (IWC 2008)."

This study has addressed concerns that the earlier jack-knife results (based on a one-year sampling unit) put forward by Walløe (IWC, 2012) did not constitute a sufficient demonstration that the precision with which the trend in blubber thickness had been estimated was such as to confirm statistical significance at the 5% level. The test carried out above show no evidence of auto-correlation amongst years of sufficient size to negate this result,

We therefore suggest that this issue might be considered by the Scientific Committee to have been resolved. These JARPA data have demonstrated an important trend to have occurred in the Antarctic ecosystem over the past two decades.

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