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Oceanographic Variability and Changes in Antarctic Krill Abundance at South Georgia

by

Phil Trathan, Andy Brierley[1], Mark Brandon[2] and Doug Bone

Biological Sciences Division, British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET UK.
Tel: +44 (0)1223 221602; Fax: +44 (0)1223 362616; email: p.trathan@bas.ac.uk

[1] Now at Gatty Marine Laboratory, University of St. Andrews, Fife, Scotland, KY16 8LB UK. [2]Now at Department of Earth Sciences, The Open University, Milton Keynes MK7 6AA, UK.

Abstract

Oceanographic data were collected to the north of South Georgia (southwest Atlantic) during three consecutive summers (1996/97, 1997/98, 1998/99). Mesoscale oceanographic variability was evident between years. During 1997/98, the near-surface potential temperature minimum was much colder and much shallower than in other years and was consistent with the presence of waters originating from further south than South Georgia. The oceanographic changes during the 1997/98 season are interpreted as a mesoscale or large scale movement of the southern Antarctic Circumpolar Current front. Acoustic densities of Antarctic krill sampled during the three summers showed consistent patterns between years; densities were substantially higher over the shelf compared to off shelf and were higher to the east of the island. During 1997/98, acoustic densities of krill were substantially higher than in other years. The coincidence of the elevated acoustic density estimates and the cooler oceanographic conditions is explored. Historical data indicate that the only other occurrence of such a high density estimate at South Georgia, was when oceanographic conditions were also colder. This relationship has the potential to improve management methods for the commercial fishery.

Introduction

During the December-January period of 1996/97, 1997/98 and 1998/99 the *RRS James Clarke Ross* carried out combined oceanographic and biological cruises to the north of South Georgia. Each year two study areas were occupied (Figure 1). These areas are known as the Western Core Box (WCB) and the Eastern Core Box (ECB) and form part of a long-term study designed to investigate the inter-annual biological variability across the northern Scotia Sea.

Each Core Box comprised ten transects and a series of stations. Physical measurements, including temperature and salinity, were collected along the transects with a *Chelsea Instruments NvShuttle* undulating oceanographic recorder (UOR) and at the stations with a *Sea-Bird* conductivity-temperature-depth sensor (CTD). Biological variables were sampled along the transects and included dual frequency bio-acoustic data collected with a *Simrad EK500* scientific echo sounder operating at 38 kHz and 120 kHz.

Physical data

Inter-annual variability was evident in the oceanographic environment at South Georgia. This variability was evident in both the transect-based UOR data and station-based CTD data. The deep off shore CTD station situated at the north-eastern corner of the ECB demonstrates the scale of this variability. This station was sampled to near-bottom during each cruise and therefore recorded differences in potential temperature and salinity that were indicative of differences in water column structure.

The depth of the near-surface potential temperature minimum (θ minimum) at this deep station differed between years, being 115, 83 and 129 dbar in 1996/97, 1997/98 and 1998/99 respectively. The temperature at the θ minimum also varied between years, being respectively 0.68°, -0.65° and 0.35°C (Figure 2).

The θ minimum at the deep station was thus shallower and colder in 1997/1998. During that year the water properties were consistent with the station lying south of the southern Antarctic Circumpolar Current front (SACCF) (Orsi et al., 1995). In contrast, during 1996/97 and 1998/99 the water properties were consistent with the station lying north of the SACCF. The change in water structure during 1997/1998 may have been the result of either a mesoscale intrusion of water with more southerly characteristics, or due to a large scale movement of the front.

Biological data

Inter-annual variability was also evident in the dual frequency bio-acoustic data. For example, variability was present in the echo signals that reflected the mean weight density of Antarctic krill (*Euphausia superba*).
For this analysis we used differences between the mean volume backscattering strength (s_V dB) at 38 kHz and 120 kHz (Δs_V) to differentiate between different categories of acoustic target. A Δs_V (120 kHz - 38 kHz) of between 2 and 12 dB was used to discriminate Antarctic krill from other macro-zooplankton and nekton species (Madureira et al., 1993).Having identified the echo signals that were attributable to krill (on the basis of Δs_V), we used the 120 kHz echo signals to derive a mean weight density estimate (g m^{-2}). We apportioned the density values of krill into four strata, off shelf and on shelf in the WCB, and off shelf and on shelf in the ECB (Figure 3). A full description of the statistical methodology that we used is given in Jolly and Hampton (1990).

The results showed that the acoustic density of krill in the WCB was generally lower than that in the ECB; the only exception being 1998/1999 when they were more or less the same. The results also indicated that the density of krill off shelf (in water deeper than 500 m) was substantially lower than that on shelf. Further, the results showed that during the 1997/1998 survey the acoustic density of krill was substantially higher than that in other years.

Bio-physical interactions

To relate the bio-acoustic data to the UOR oceanographic data from both Core Boxes for all three years, we used generalized additive models (GAM). These showed that the mean weight density of krill, at the scale of the individual transect, could be modelled using water temperature data.

In this analysis the residual variance was reduced (58%) when compared with the null model and the model terms were highly significant ($p < 0.001$), indicating that the model was a reasonable fit to the data.

The GAM model suggests that temperatures within the range 1.50° to 2.25°C have a near-linear relationship with the mean weight density of krill, and that low temperatures are associated with high levels of krill and that high temperatures are associated with low levels of krill. Above 2.25°C the model showed that temperature had little or no relationship with the mean weight density of krill (Figure 4).

Historical perspectives

The biomass of krill at South Georgia is known to fluctuate markedly, with periods of relative scarcity and periods of much higher abundance. Periods of particular abundance include January 1992 and January 1998, with 95.0 and 150.5 g m^{-2} respectively. These latter values are particularly extreme and reflect biomass estimates that are more than 20 g m^{-2} higher than the next nearest values.

Historical sea surface temperature data indicate that these periods of high biomass occurred during periods of cooler oceanographic conditions when temperatures were more than 1°C colder than average.

Conclusion

The relationship between temperature and abundance of Antarctic krill at South Georgia suggests that predicting the abundance of krill prior to the fishing season may become a future possibility. In this case there will be considerable potential for improving existing management methods and ensuring better resource utilization by the commercial fishery.

References

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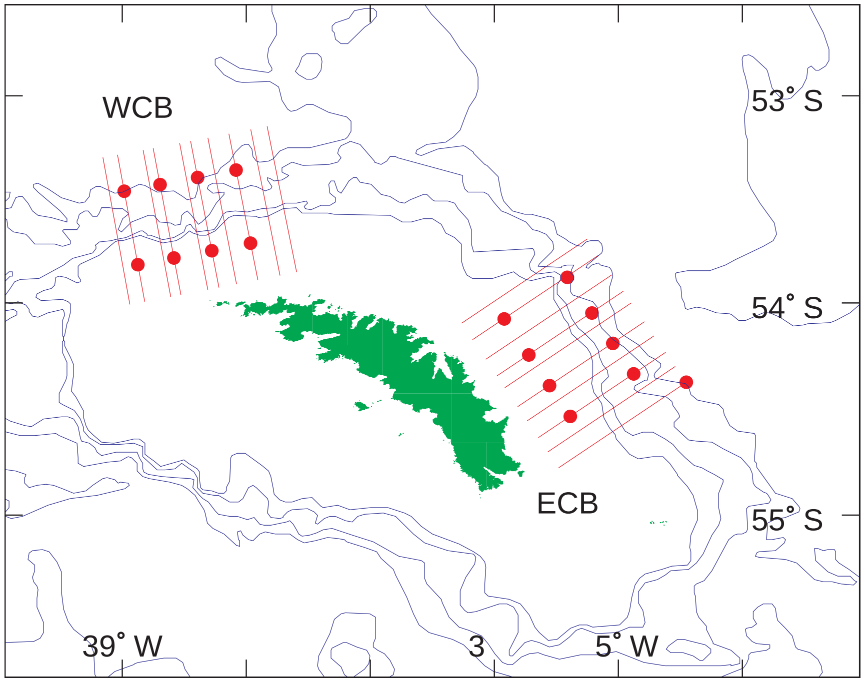

Fig. 1. Plot of the study area showing the Western Core Box and the Eastern Core Box. UOR transects are shown as solid lines and CTD stations as filled circles. The 500, 1000, 2000 and 3000 m isobaths are shown.

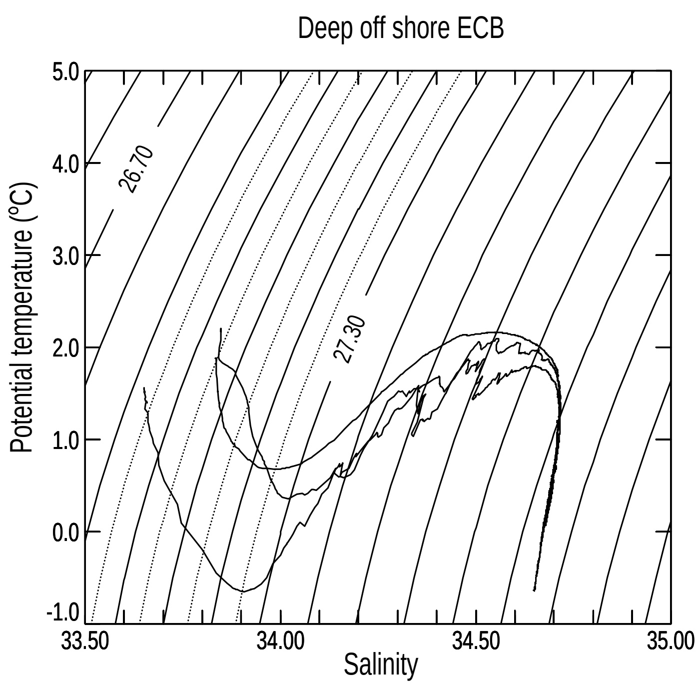

Fig. 2. Potential temperature (°C) and salinity data from the deep off shore CTD station located at the northeastern corner of the ECB. Data from 1996/1997, 1997/1998 and 1998/1999. Density surfaces (kg m^{-3}) are shown as curved contours.

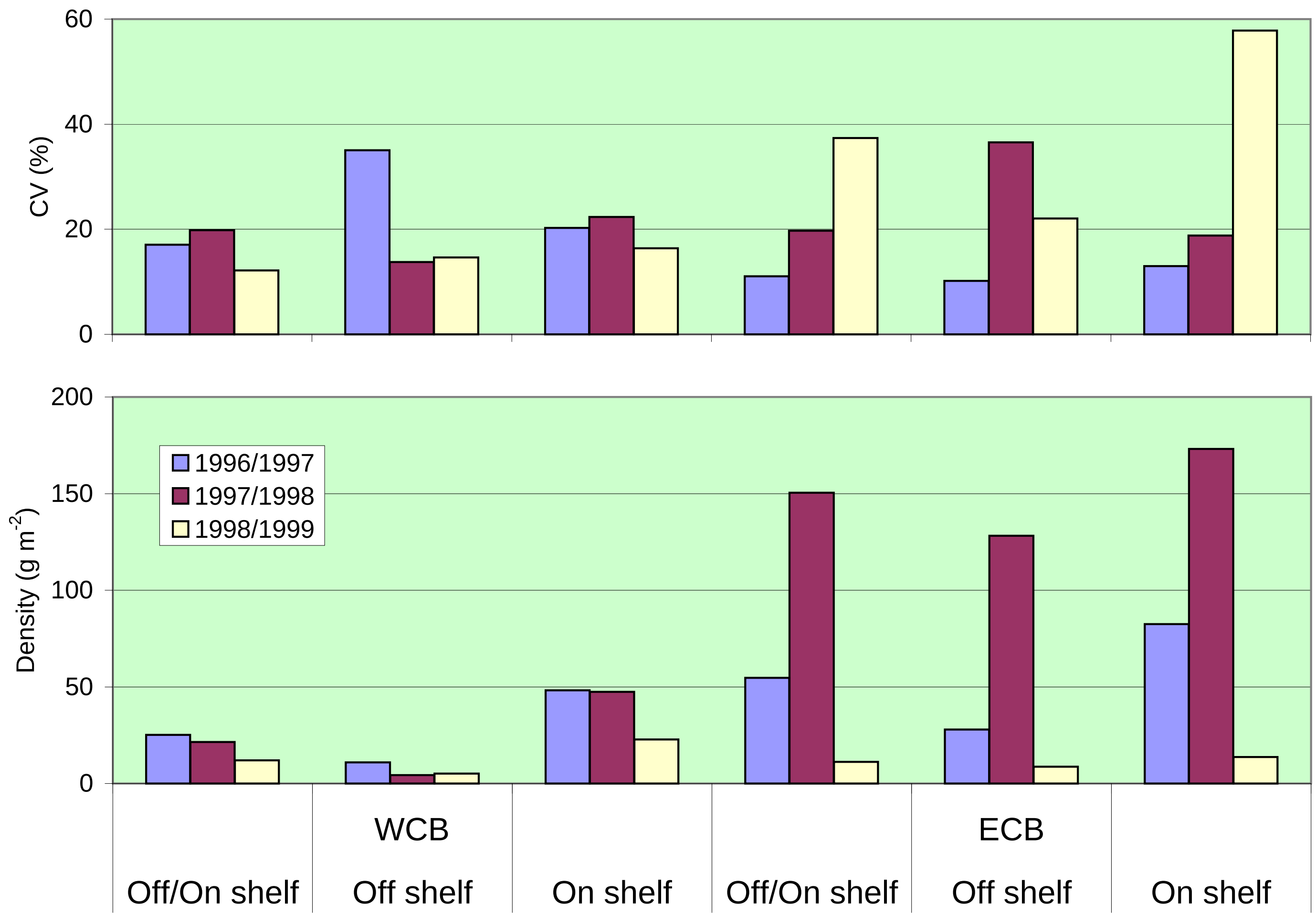

Fig. 3. Acoustic density (and coefficient of variation) of krill during 1996/1997, 1997/1998 and 1998/1999. Estimates calculated for off shelf portions of transect (depth > 500 m) are shown separately from those on shelf (depth < 500 m).

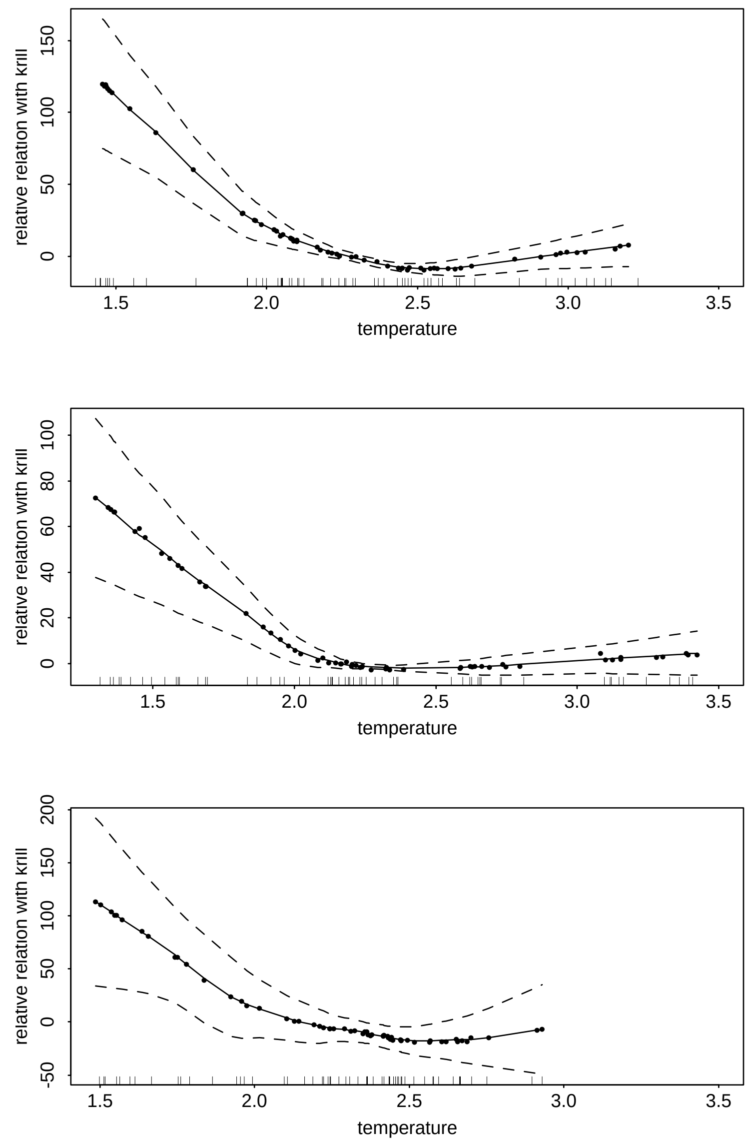

Fig. 4. GAM models for estimating the mean weight density (g m^{-2}) of krill from the predictor temperature (°C). The ordinand axes represent the relative importance of the predictor on the response variable. The points show the residuals for each acoustic transect; the predicted model is shown by the solid line and the 95% confidence intervals by the hashed lines. (Top panel) Model using all resets from a transect; (Middle panel) model using only off shelf resets (depths greater than 500 m), and; (Bottom panel) model using only on shelf resets (depths less than 500 m).

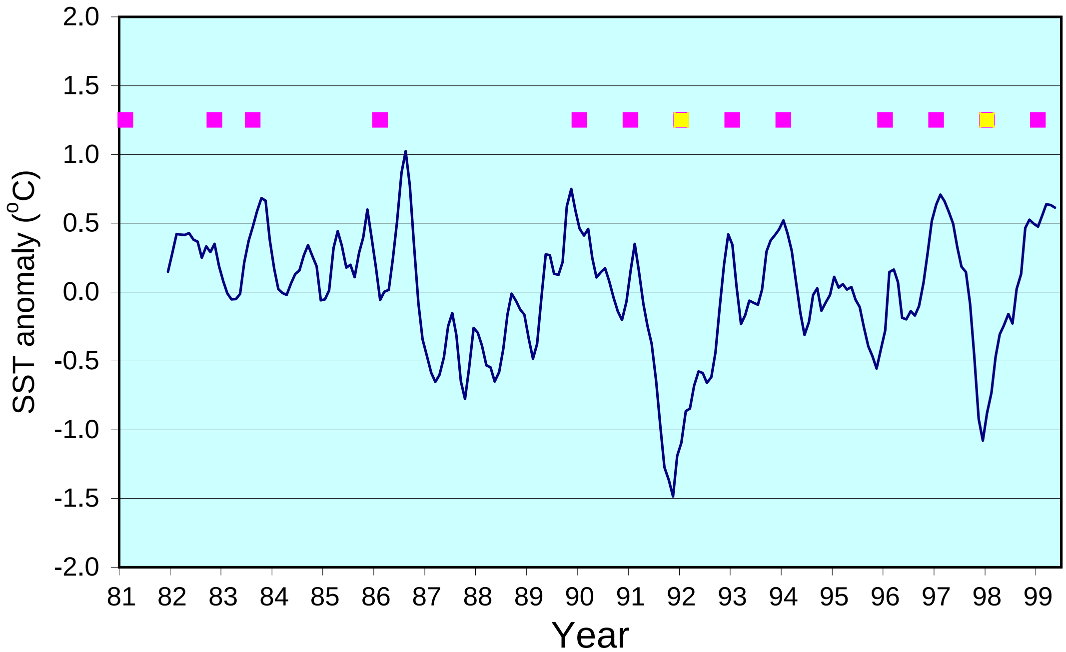

Fig. 5. Sea surface temperature anomaly data for November 1981 to June 1999 for a grid position to the east of South Georgia (53° 30´ S, 38° 30´ W); a 3 month running average has been applied to the data. Months when acoustic surveys were carried out at south Georgia (□); high abundance surveys (ν).