APPENDIX G

REPORT OF THE B_0 WORKSHOP
(La Jolla, USA, 30 May to 9 June 2000)

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INTRODUCTION

1.1 A workshop to analyse data from the CCAMLR-sponsored multinational, multiship acoustic survey for krill biomass in Area 48 undertaken in January and February 2000 was held at the Southwest Fisheries Science Center, La Jolla, California, from 30 May to 9 June 2000. The workshop was convened by Dr R. Hewitt (USA). A List of Participants is included in this report as Attachment A.

1.2 Dr R. Neal, Deputy Director, Southwest Fisheries Science Center, welcomed participants to the workshop and wished them a profitable meeting.

1.3 A Provisional Agenda had been prepared by the Convener and this was adopted. The Agenda is included as Attachment B.

1.4 This report was prepared by Dr I. Everson (UK) in consultation with workshop participants.

Aims

1.5 The primary aims of the workshop had been agreed by WG-EMM at its 1999 meeting as the estimation of B_0 of Antarctic krill (*Euphausia superba*) and its associated variance in CCAMLR Statistical Area 48 (SC-CAMLR-XVIII, Annex 4, paragraph 8.37). It had been agreed that a key step in this estimation would comprise a multiship acoustic survey of Area 48 (CCAMLR-2000 Survey) to be undertaken in early 2000 (SC-CAMLR-XVIII, paragraph 6.36).

1.6 The workshop noted that the term 'B_0' denotes a krill standing stock being estimated (SC-CAMLR-XII, paragraphs 2.39, 2.41 to 2.47). It is used as a proxy for krill pre-exploitation biomass in the CCAMLR Generalised Yield Model (GYM) used to estimate krill sustainable yield, and to scale the krill biomass probability distribution over time in the estimation of γ with the GYM. In this report 'B_0' and 'standing stock' are used interchangeably.

1.7 WG-EMM would use the estimate of B_0 produced by the workshop to estimate potential yield using the GYM. This would be used to advise on a precautionary catch limit for Area 48, and this precautionary catch limit would be subdivided for smaller management areas as appropriate (SC-CAMLR-XVIII, Annex 4, paragraph 8.50).

1.8 WG-EMM had considered several methods by which catch limits might be subdivided and had agreed that the most tractable were likely to be by proration by:

(i) the proportion of the survey in each statistical subarea where the proportions are estimated from the lengths of survey tracks (SC-CAMLR-XVIII, Annex 4, paragraphs 8.55(iii) and 8.61); and

(ii) the area of krill distribution in each statistical subarea (SC-CAMLR-XVIII, Annex 4, paragraphs 8.55(iv)(b) and 8.61).

1.9 The workshop had been requested to provide estimates of the relative proportions of the survey track length within each statistical subarea (SC-CAMLR-XVIII, Annex 4, paragraph 8.61).

Preparation

1.10 Plans for the CCAMLR-2000 Survey had been set in motion during the 1996 WG-EMM meeting. The underlying theme was that since the krill biomass estimate from the 1981 FIBEX survey, on which the current CCAMLR precautionary catch limit for krill is based, had been made 15 years previously, a new estimate of this limit was a high priority. While a standing stock estimate remained the primary aim, it was recognised that additional oceanographic sampling during the CCAMLR-2000 Survey could provide much new information of value to ecosystem assessments undertaken by WG-EMM. The scope of the overall study had as a result been broadened whilst still retaining the same primary objective as outlined in paragraph 1.5.

1.11 Plans for the CCAMLR-2000 Survey had been finalised at a meeting in Cambridge, UK, in 1999 (SC-CAMLR-XVIII, Annex 4, Appendix D). At that meeting the main survey transects were delineated, methods for krill sampling agreed and the scope of ancillary sampling discussed.

1.12 The following computing facilities were available at the workshop: five computers were running Windows 2000 and had the acoustic data analysis software Echoview, Versions 1.51.38 and 2.00.62 installed. All computers had the package Microsoft Office and two had the numerical analysis packages Surfer, Transform and MatLab installed. All computers were networked to a central file server, colour and black and white printers and a video projector. Additional computers were made available on the network as needed.

INFORMATION AVAILABLE AT THE WORKSHOP

Survey Design

2.1 The CCAMLR-2000 Survey design had been agreed by WG-EMM in 1999 and consisted of a large-scale survey to cover much of Subareas 48.1, 48.2, 48.3 and 48.4 with randomly spaced transects. This large-scale survey was divided into three strata. Within the large-scale area there are four mesoscale regions that are considered to have a high abundance of krill and therefore to be of importance to commercial fishing fleets. These regions lie to the north of South Georgia, north of the South Orkney Islands, and north of the South Shetland Islands, and around the South Sandwich Islands. Additional mesoscale strata were designated for these regions. In some instances the large-scale survey transects crossed the mesoscale survey boxes. The sections of large-scale survey transects which went through these are indicated in Table 1. These were excluded from the analyses.

Definition of Strata

2.2 The area surveyed within each stratum was calculated from the nominal transect lengths and the 125 km wide zone within which each transect was placed (see Figure 1a, b, c). The land and mesoscale survey areas were excluded from the estimated areas for the large-scale survey.

2.3 The estimated strata areas were as follows:

Large-scale strata:

Antarctic Peninsula	473 318 km^2
Scotia Sea	1 109 789 km^2
East Scotia Sea	321 800 km^2

Mesoscale strata:

South Shetland Islands	48 654 km^2
South Orkney Islands	24 409 km^2
South Georgia	25 000 km^2
South Sandwich Islands	62 274 km^2

2.4 At WG-EMM-99 it had been agreed that sampling according to the design outlined above would be used for the estimation of standing stock in Area 48. However, it was recognised that additional sampling programs would be in progress within Area 48 at approximately the same time as the CCAMLR-2000 Survey. It had also been agreed that data arising from such surveys should not be included in the analyses leading to the estimation of B_0, but would provide useful information to support the Area 48 B_0 analysis.

Sampling Program

B_0 Sampling

2.5 Vessels from Japan (*Kaiyo Maru*, Scientist-in-Charge (SIC) Dr M. Naganobu), Russia (*Atlantida*, SIC of Acoustic Program, Dr S. Kasatkina), UK (*James Clark Ross*, SIC Dr J. Watkins) and USA (*Yuzhmorgeologiya*, SIC Dr Hewitt) had participated in the CCAMLR-2000 Survey. The survey tracks of all participating vessels are shown in Figure 2.

2.6 All participating vessels were equipped with Simrad EK500 echosounders operating at 38, 120 and 200 kHz (Tables 2 and 3). Echosounders were set according to protocols agreed at the planning meeting (paragraph 1.11 above; SC-CAMLR-XVIII, Annex 4, Appendix D). On each vessel, acoustic data were logged using the SonarData echolog_EK Version 1.50 software.

Survey Activities

2.7 SICs on each vessel gave a brief presentation outlining key results from their respective research cruises. Summary information on the cruises of direct relevance to the workshop aims is set out in Table 4. All vessels undertook a sampling program more extensive than the requirements of the CCAMLR-2000 Survey protocol. Details of this additional sampling are set out in Table 5.

2.8 Dr Watkins noted that the *James Clark Ross* had encountered a large number of icebergs in the vicinity of Shag Rocks and the southern side of South Georgia (Subarea 48.3). This caused the vessel to divert from the planned survey transect (SS07). It was noted that this may be a more general problem with other transects (see also paragraph 3.51).

2.9 Due to adverse weather conditions causing the vessel to fall behind schedule, the fifth transect (AP13) allotted to the *James Clark Ross* had been sampled from north to south, (the reverse direction to that of the original plan). Time constraints meant that the last 100 km of the final transect (AP19) had not been sampled by the *James Clark Ross*.

2.10 Dr Kasatkina reported that the *Atlantida* had undertaken a large-scale and mesoscale survey in the vicinity of the South Sandwich Islands (Subarea 48.4) according to a plan designed to fit into the overall CCAMLR-2000 Survey plan agreed by WG-EMM (SC-CAMLR-XVIII, Annex 4, paragraphs 8.4 to 8.6). All transects on the survey had been sampled.

2.11 Dr Kasatkina reported that an acoustic calibration of the *Atlantida* had been undertaken in Horten, Norway, prior to the vessel heading south to participate in the CCAMLR-2000 Survey. The second acoustic calibration, (the first calibration for the CCAMLR-2000 Survey), had been made at Stromness Harbour, South Georgia. High winds had made this calibration very difficult. The second calibration for the survey was undertaken under much more favourable weather conditions at the end of the survey.

2.12 In Subarea 48.4 (South Sandwich Islands) the interaction of two Antarctic water masses was observed: cold water of the Weddell Sea and warmer water of the southern flow of Antarctic Circumpolar Current. The boundary between the two water masses represented the Weddell Gyre frontal zone. Northward transport of cold Weddell Sea waters along the South Sandwich Islands arc was observed up to 54°S. In general, species composition of catches was mixed (krill, other euphausiids, juvenile fish, jellyfish, myctophids, salps). Krill ranging from 21–60 mm total length were caught. The highest krill catches were observed in the Weddell Sea Water.

2.13 Dr Naganobu noted that during Leg 1 of their cruise, the *Kaiyo Maru* had undertaken a mesoscale survey as part of the International Coordination Study in the vicinity of the South Shetland Islands (Subarea 48.1), before commencing the CCAMLR-2000 Survey (SC-CAMLR-XVIII, paragraph 5.10). Leg 2 of the cruise was the CCAMLR-2000 Survey and this had been undertaken without difficulty. Also during Leg 2 a second mesoscale survey was conducted in the vicinity of the South Shetland Islands that was part of the CCAMLR-2000 Survey.

2.14 Dr Hewitt noted that the *Yuzhmorgeologiya* had undertaken the CCAMLR-2000 Survey as planned although due to time constraints the final part of the last transect (AP17) had been curtailed. He also noted that since relatively few large acoustic targets had been encountered, only a small number of targeted net hauls had been undertaken. Surface chlorophyll measurements in Subarea 48.1 confirmed the observations from SeaWIFS satellite data that there is tongue of oligotrophic water offshore of the South Shetland Islands.

2.15 In general discussion it was noted that target net hauls had indicated that myctophids were present in deep water (>300 m). It was therefore likely that they might be the cause of most of the acoustic backscatter in deep water attributable to biological targets.

2.16 Two shallower target tows, that had been aimed at scatterers which were assumed to have been krill, caught *Themisto gaudichaudii* (Amphipoda) and *Thysanoessa*.

2.17 All vessels had encountered large numbers of icebergs in the vicinity of South Georgia. These were thought to have been due to the breakup of two large icebergs – A10 which had come from the Weddell Sea and B10 from the Bellingshausen Sea.

National Surveys

Korean Survey

2.18 Dr D. Kang (Republic of Korea) described a cruise to estimate the abundance and distribution of krill in the vicinity of the South Shetland Islands where a hydroacoustic survey was conducted by the RV *Onnuri* as a part of the Korea Antarctic Research Program. The survey was conducted from 9 to 19 January 2000 using a Simrad EK500 echosounder operating at 38, 120 and 200 kHz. The acoustic data were obtained from the eight transects comprising the South Shetland Islands mesoscale box (total transect length = 459 n miles, area = 38 802 km^2). Krill were collected using Bongo nets (mesh size: 0.333 mm, 0.505 mm) to determine their size composition and stage of development. In addition, a Conductivity Temperature Depth probe (CTD) and on-station Acoustic Doppler Current Profiler (ADCP) were used to understand the physical structure of the water column at 11 stations.

2.19 The length–weight relationship of krill sampled during the survey was $w = 0.0035\ L^{3.2108}$ where w was the mass (mg) and L was the total length (mm); the median length was 50 mm. The conversion factor for integrated volume backscattering to areal krill biomass density at 120 kHz was 0.1556. The mean density of krill in the area surveyed was 12 g/m^2 with a coefficient of variance of 14.5%. Krill swarms with relatively higher densities appeared to the north of Smith Island, north and east of King George Island, and north and south of Elephant Island. The mean density of krill observed during the survey was much lower than that observed during a similar survey in 1998 (151 g/m^2).

US AMLR Survey

2.20 Mesoscale sampling in the vicinity of Elephant Island, undertaken by the *Yuzhmorgeologiya* as part of the US AMLR Program, was described by Dr Hewitt. The design consisted of three survey boxes: one to the north of the South Shetland Islands, one north of Elephant Island and the third south of the eastern end of the South Shetland Islands. As in previous years, a sharp frontal zone was noted north of the South Shetland Islands shelf break and this became more diffuse towards Elephant Island. Mean densities of krill were 28 g/m^2 in the northern South Shetland box, 26 g/m^2 in the Elephant Island box and 17 g/m^2 in the southern South Shetland box.

2.21 The variations in the krill density estimates over the past eight years in the Elephant Island area were described by a cyclical function (Hewitt and Demer, in press). The relatively low standing stock observed during the survey was considered to be indicative of poor recruitment over recent seasons; 1994/95 producing the last strong year class.

Japanese Survey

2.22 A survey along the northern side of the South Shetland Islands undertaken by *Kaiyo Maru* was described by Dr Naganobu. The survey was carried out by sampling closely spaced stations in and around the krill fishing grounds. Data on seasonal krill flux during the 1999/2000 season were collected during a series of repeat surveys. The first survey was undertaken in December 1999 and the second in January and February 2000. Large-scale oceanographic transects were sampled using CTD along two longitudinal sections: one in the Drake Passage (WOCE Line SR1) and the other in the Indian Ocean sector. A series of 12 laboratory experiments was undertaken aboard the vessel to estimate the instantaneous growth rate of krill. A further 500 individual krill were transported alive to Japan for further biological experiments.

Russian Survey

2.23 A small-scale survey at South Georgia that had been planned as part of the BAS Core Program could not be undertaken by *James Clark Ross* due to unforeseen circumstances. That survey was undertaken by the *Atlantida* and the results will be analysed at a joint workshop between scientists from Russia and the UK.

Krill Length Frequencies

2.24 Krill length-frequency data from the station hauls sampled by all vessels participating in the CCAMLR-2000 Survey had been analysed by Dr V. Siegel (Germany). The analysis had been undertaken in two parts: an agglomarative hierarchical cluster analysis to determine whether there were recognisable groupings of krill length-frequency distributions over the survey area, and a geographical consideration of the distribution of such clusters.

2.25 Four types of linkage method were used to compare the results from the different fusion methods on the station groupings:

(i) single linkage;
(ii) complete linkage;
(iii) unweighted Pair Group Average (UPGA); and
(iv) Ward's Method.

2.26 In the first step, each object (station) represents a cluster of its own and the distance between objects is determined by the distance measure (e.g. Euclidean Distance). In principal, objects which have a minimal distance value (single linkage) are fused. Another approach is to group objects (stations) into different (dissimilar) clusters by identifying the maximum distance (furthest neighbour, complete linkage). The latter method is usually recommended for data which naturally form groupings of objects.

2.27 The results of the single linkage method showed no separation of stations into distinct clusters, but the dendrogram formed a 'chain' of stations. This often occurs if few objects have similar distance values. Results from all other three linkage methods clearly indicated a separation of stations into at least three distinct clusters.

2.28 Interpretation of the results using Ward's method caused some difficulty since, from the dendrogram, Cluster 2 appeared to be more similar to Cluster 1 than to Cluster 3, although the resulting overall length-frequency distribution of Cluster 1 was distinctly different from those of Clusters 2 and 3 (see below).

2.29 The UPGA method uses the average distance between all pairs of objects (stations). The dendrogram of this linkage showed a greater similarity between Clusters 2 and 3 and a greater dissimilarity of these two to Cluster 1. This was in concordance with the resulting composite length-frequency distributions of the relevant clusters.

2.30 The complete linkage method (using the greatest instead of the average distance) provided a dendrogram very similar to the UPGA method, and the three clusters were even more distinct than for the previous method. Therefore, the result of the complete linkage method was thought to be the most appropriate to describe the geographical distribution of the various clusters and the related composite length-frequency distributions (Figure 3). Grouping the length-frequency distributions, weighted by catch rates, indicated that each of the clusters had a reasonably tight length-frequency distribution. The aggregated length-frequency distributions are shown in Figure 4.

2.31 The locations of hauls on which these clusters were based fitted into a pattern which appeared similar to the water circulation pattern in the region (paragraphs 2.33 to 2.38). Cluster 1 was composed of small krill of median length 26 mm and occurred from the northern sector of the Weddell Sea and extended across to the north of South Georgia. The distribution of Cluster 2, with a median length of 48 mm, extended from the Bransfield Strait eastwards to the east of the South Orkney Islands, then across the Scotia Sea to the north of South Georgia and the northern part of the South Sandwich Islands. The distribution of Cluster 3, median length 52 mm, extended from the Drake Passage eastwards to include Elephant Island and the South Orkney Islands. The distribution of the clusters is shown in Figure 5 and the latitudinal positions of the cluster boundaries along the transects are indicated in Table 6.

2.32 A small subgroup discussed the future analysis of zooplankton samples. Its report is included as Attachment C.

Physical Oceanography

2.33 A summary of physical oceanographic information was provided by Dr M. Brandon (UK). Routine collection of physical oceanographic data formed an integral part of the CCAMLR-2000 Survey. Data from 157 oceanographic stations sampled by the *Kaiyo Maru*, *James Clark Ross* and *Yuzhmorgeologiya* were available in advance of the workshop. Together with data from the remaining stations sampled from the *Atlantida*, these data represent the largest synoptic dataset since FIBEX in 1981. In comparison with the FIBEX study the CCAMLR-2000 Survey covered a greater area.

2.34 All sampling was undertaken according to predetermined protocols and the submitted data had been combined into an overall database. Plots of potential temperature against salinity indicated very good consistency between sampling vessels. This enabled mapping of key water masses across the region.

2.35 Considering the transects from west to east, the main direction of flow of the Antarctic Circumpolar Current, the constraining effect of the Drake Passage was clearly evident in the proximity of the Southern Antarctic Circumpolar Current Front and the Continental Water Boundary. Both these fronts were close to the Antarctic Peninsula. Similarly the Sub-Antarctic Front and Antarctic Polar Front were close together at the central section of the Drake Passage.

2.36 As the Antarctic Circumpolar Current enters the Scotia Sea it becomes less topographically constrained and spreads out. Although a large dataset was collected during the CCAMLR-2000 Survey, it was not sufficient to resolve individual eddies.

2.37 All of the transects were south of the Polar Front. The Weddell Scotia Confluence is observed extending from the Antarctic Peninsula to the vicinity of the South Orkney Islands. Proceeding further east, and particularly in the region east of the South Orkney Islands, Weddell Sea Water becomes the dominant water mass.

2.38 The general distribution of water masses over the region during the CCAMLR-2000 Survey is shown in Figure 6.

METHODS

Acoustic Data Preparation

3.1 The steps required to produce an estimate of B_0 from acoustic data as agreed at WG-EMM-99 (SC-CAMLR-XVIII, Annex 4, paragraphs 8.41 to 8.49) were reviewed. The steps are:

(i) Delineate volume backscattering attributed to krill from all other volume backscattering. Two methods were proposed to accomplish this step: one based on the difference between mean volume backscattering strength (MVBS) at 120 and 38 kHz, the other based on an algorithm that makes use of volume backscattering at three frequencies. Once volume backscattering attributed to krill was delineated, it would be summed over a depth range and averaged over a time/distance interval (integrated).

(ii) Convert integrated backscattering area attributed to krill to areal krill biomass density. Two methods were proposed to accomplish this step: one using length-frequency data to estimate a distribution of target strengths (TS) based on the TS-length model adopted by SC-CAMLR in 1991, and the other using *in situ* TS measurements. The workshop agreed to make initial assessments using published TS to size relationships and, if time permitted, to extend the assessments using *in situ* TS results.

(iii) S areal krill biomass densities over the survey area. Two methods were proposed to accomplish this step: one is an application of the method of Jolly and Hampton (1990), which assumes that the mean density for each transect within a stratum is a representative sample of the stratum mean, and the other uses an approach based on geostatistical methods. The workshop agreed to use the Jolly and Hampton method.

(iv) Estimate the uncertainty associated with an estimate of B_0. It was agreed that the estimate of uncertainty should include both sampling errors (transect to transect variance) and measurement errors.

3.2 The workshop agreed that the 120 kHz data should be used for the estimation of krill standing stock. Data at 38 and 200 kHz would be used along with those at 120 kHz to aid with target delineation and also provide information to incorporate into the estimate of uncertainty of the standing stock estimate.

3.3 Acoustic datasets from all participating vessels were available for analysis at the workshop. These included raw data (EK5 files), annotations including positional data (EV files), calibration data, transect start and stop times, and noise measurements.

3.4 Recent developments had been made with the Echoview software and these were described to the workshop by Mr I. Higginbottom (SonarData, the Echoview developer). The main advances from Version 1.51 to Version 2.00 had been to permit the simultaneous analysis of data from multiple frequencies and echosounders.

3.5 Version 1.51 EV files had been submitted prior to the workshop by SICs for each participating survey vessel. These were converted to Version 2.00 EV files for use at the workshop. However, several questions remained to be resolved before the EV files could be used to address the steps outlined in paragraph 3.1.

3.6 After some discussion it was agreed that prior to integrating and analysing the acoustic data, consideration needed to be given to the following: draft correction, allowance for noise, surface layer exclusion, calibration, sound velocity, absorption coefficient, wavelength, bottom detection algorithm, transect sections to be excluded and equivalent two-way beam angle.

Draft Correction

3.7 The workshop considered that no changes were needed to the draft correction for any of the vessels. A draft correction for the *James Clark Ross* had to be removed.

Allowance for Noise

3.8 Two general methods were considered:

(i) setting a threshold (either fixed or time-varied) and accepting all integrated values greater than the threshold (termed the thresholding approach); and

(ii) estimating a time-varied volume backscattering strength due to noise and subtracting this from integrated values (termed the subtraction approach). In the case of negative values being derived these were reset to -999 dB.

3.9 The workshop concluded that the subtraction approach would provide better estimates of volume backscattering strength (S_v). Initial estimates of noise at each frequency on each transect as provided by SICs were used. During subsequent inspection of echograms several noise levels were modified. The final values used are listed in Table 7.

Calibration

3.10 Calibration was an integral part of the overall CCAMLR-2000 Survey plan with two calibration periods scheduled for each vessel. Calibrations were undertaken prior to the start of the survey at Stromness Harbour, South Georgia, by all vessels. The second calibration was undertaken on completion of the survey at Stromness by the *Atlantida* and at Admiralty Bay, King George Island by the other three vessels.

3.11 All calibrations were undertaken using the standard sphere method. Dr D. Demer (USA) had obtained a set of 38.1 mm diameter Tungsten Carbide spheres from the same manufacturing lot. He had arranged for these spheres to be bored and fitted with monofilament loops. These spheres had been distributed to the SIC on each vessel. Standard copper spheres 60, 23 and 13.7 mm diameter, provided by each vessel, were also used for calibration.

3.12 Temperature and salinity at the calibration sites were similar and within the range of a large part of the CCAMLR-2000 Survey area. In a few instances inclement weather had slightly prejudiced the quality of the results, but in spite of this all calibrations were within or close to the specification for the equipment. For the *Yuzhmorgeologiya* and the *James Clark Ross* the mean values of the two calibrations were used. For the *Atlantida* the second calibration and for the *Kaiyo Maru* the first calibration were considered to be the better of the two. The measured values of S_v gain and TS gain along with those selected for application to the acoustic analyses are shown in Tables 8 and 9. Summary calibration data from each survey vessel are set out in Table 10 and details of the calibration parameters are set out in Table 11.

Sound Velocity (c)

3.13 In advance of the CCAMLR-2000 Survey a default value for the velocity of sound in water (c), derived from CTD analyses in previous seasons, of 1 449 m/s had been agreed. Physical oceanographic sampling during the survey indicated that a better estimate for c would be 1 456 m/s. Although only a slight modification, the workshop agreed that data should be analysed using this value.

Absorption Coefficient (α)

3.14 The absorption coefficient (α) is dependent on sound velocity, temperature and salinity. Default values of α had been agreed in advance of the CCAMLR-2000 Survey; these were 0.010 dB/m at 38 kHz, 0.026 dB/m at 120 kHz and 0.040 dB/m at 200 kHz. Using the equations of Francois and Garrrison (1982), the following revised values, appropriate to the actual survey conditions, were agreed: 0.010 dB/m at 38kHz, 0.028 dB/m at 120 kHz and 0.041 dB/m at 200 kHz.

Wavelength (λ)

3.15 The slight change in the accepted value of sound velocity required a recalculation of the wavelength. Using the nominal resonant frequency of the transducers the following values were determined for wavelength (λ):

200 kHz:	1 456/200 000	=	0.00728 m
120 kHz:	1 456/119 050	=	0.01223 m
38 kHz:	1 456/37 880	=	0.03844 m

Bottom Detection Algorithm

3.16 Bottom as detected by the EK500 was visually verified from the echograms and adjusted, if necessary, to ensure that bottom echoes were excluded from the integrated layers.

Equivalent Two-way Beam Angle

3.17 This parameter, provided by the manufacturer for a nominal sound speed of 1 473 m/s, was adjusted for a sound velocity of 1 449 m/s by the *James Clark Ross* and the *Atlantida* and set in the EK500 prior to the CCAMLR-2000 Survey. No such adjustments were made for the *Kaiyo Maru* and the *Yuzhmorgeologiya* prior to the survey. The workshop accepted that no additional change was necessary (see Table 12).

Surface Exclusion Layer

3.18 A surface layer exclusion depth of 15 m had been applied to data from the *Yuzhmorgeologiya* and the *Atlantida*, and 20 m for data from the *James Clark Ross* and the *Kaiyo Maru*. These values had been set by the various operators based on previous experience. Whilst there might be some merit in standardising the depth for analysis, it was agreed that given that krill may occur near the surface, it was important to review the data files and make adjustments to include any near-surface targets or exclude any intensive surface noise spikes. This was carried out by a combination of changing the overall depth of the surface exclusion layer or editing small fragments of the surface exclusion layer around individual targets (see Table 7 for details).

3.19 The foregoing decisions on values for draft correction, noise, calibration, sound velocity, absorption coefficient, wave length, bottom detection and two-way beam angle were incorporated into revised EV files for each transect (Table 10).

3.20 Each participating group had provided a complete set of data at the three frequencies. Consequently the datasets included data collected during the following types of activity:

(i) large-scale synoptic survey transects;
(ii) mesoscale survey transects;
(iii) net hauls;
(iv) CTD stations;
(v) calibrations; and
(vi) vessel 'down time' due to bad weather or other causes.

3.21 All of these data are indexed by date, time and position. The date and time for the start and end of each transect are set out in Tables 13 to 19. The EV files were further annotated to include only valid acoustic transect periods after the start time, between station periods and down time along the transects, and before the end time.

Delineation of Volume Backscatter Attributed to Krill

3.22 Two options were considered for the identification of krill targets on echocharts. In the past several workers had applied a subjective visual classification to echograms with moderate success. It was accepted that that method was very much dependent on operator skill and experience and was subject to considerable individual variation even between workers at the same institute. The workshop agreed that a processing algorithm would offer a better approach by providing a formalised and objective method for analysing the data.

3.23 Dr Watkins provided an overview of a method that he and his colleagues had developed (Watkins and Brierley, 2000). The method relies on the frequency dependence of the echostrength of acoustic targets. In the acoustic domain, the ratio of the echostrengths is given as the difference between the mean volume backscattering strength (ΔMVBS) at two frequencies. The chosen frequencies were 120 and 38 kHz and the method had been developed during studies over several seasons at South Georgia (Subarea 48.3).

3.24 Applying the method of Watkins and Brierley (2000), the ΔMVBS for krill fell within the general range 2–12 dB. Although other scatterers were present in the water these generally fell outside the ΔMVBS range for krill. It was accepted that some, such as other euphausiids (*Thysanoessa* and *Euphausia frigida*) and amphipods (*T. gaudichaudii*), might be included within the krill ΔMVBS. The ΔMVBS values determined from field studies fitted reasonably closely to those from theoretical models of krill TS and size.

3.25 This approach relies on the mean density averaged over the integration depth range and distance. Providing transducers are situated close together and the echosounders are synchronised, then a ping-by-ping comparison might provide a source of information for target delineation.

3.26 Dr Demer described an approach which sought to exploit the frequency dependence allied to differences in variance between individual pixels to address this problem. He had found that one component of the variance provided a good indication as to whether the echoes arose from biological scatterers or were due to noise, the seabed or some other non-biological source. Extending this analysis to include data from the three frequencies 38, 120 and 200 kHz provided a more rigorous approach to target identification. Modelling results had supported these conclusions from field observations and the frequency dependence at 38 and 120 kHz were in agreement with the Watkins and Brierley method outlined above.

3.27 The means to implement this procedure were still under development and at the time of the workshop the processing algorithms still required some development. The workshop felt that the approach had considerable merit and should be developed, however, it was felt that with the limited time available it would be appropriate to use the Watkins and Brierley method until such time as alternatives were available. Development of such methods was considered a high priority by the group.

Implementation of Echoview 2.00.62

3.28 The workshop discussed a stepwise approach to analysing the CCAMLR-2000 Survey data. It was agreed that the first group of processing activities should lead to the production of intermediate echogram datafiles which contained only those data deemed appropriate for echointegration.

3.29 The first step in this process involved the definition of the upper and lower depth ranges. Nominal surface layer exclusion depths to define the upper depth limit had been defined for each vessel. These are included in Table 7. The lower level was set according to one of two criteria. Where the bottom depth was <500 m, the lower level of integration was set as the bottom depth less 5 m. Where the bottom depth was >500 m, the lower level for integration was set to 500 m.

3.30 The second step involved the averaging of S_v into integration bins of 5 m depth by 100 s in time. These approximate to a horizontal distance of 0.5 km when the vessel is proceeding at 10 knots.

3.31 The third step was to calculate a time-varied noise S_v for each frequency on each vessel. Using the subtraction process, revised datasets of resampled 'noise-free' S_v values at each operating frequency were generated. The noise measurement results are set out in Table 7.

3.32 The fourth step was to generate a matrix of ΔMVBS values by subtracting the resampled noise-free 38kHz values from the resampled noise-free 120kHz values.

3.33 Although krill have previously been delineated by using a general ΔMVBS window of 2–12 dB, Watkins and Brierley (2000) showed that a substantial proportion of small krill sampled in a field study around South Georgia in 1996 and 1997 were not detected using this general window, but would be detected using a range of 2–16 dB. Given that krill in the eastern area of the Scotia Sea were relatively small, it was agreed that a ΔMVBS range of 2–16 dB should be used in the present analysis.

3.34 These steps were implemented as set out in Table 20.

Methods for Converting Integrated Krill Backscattering
Area to Areal Krill Biomass Density

3.35 A factor for converting integrated backscattering area to areal krill biomass density can take the form:

$$\rho = S_A \, w/\sigma \qquad (1)$$

where ρ = areal krill biomass density
S_A = integrated backscattering area
w = krill mass
σ = acoustic cross-sectional area

where $$\sigma = 4 \, \pi \, r_0^2 \, 10^{TS/10} \qquad (2)$$

and $r_0 = 1$ m.

3.36 This factor can be considered as two components, the relationship of krill acoustic cross-sectional area to length and krill mass to length. These two can then be combined to provide a factor to convert S_A to areal krill biomass density.

3.37 The workshop used the generalised formula

$$w = aL^b \quad (3)$$

where w = total mass (mg) and L = total length (mm).

3.38 It was agreed that ideally the length to mass relationship to be used to analyse the CCAMLR-2000 Survey data should come from data collected during the survey. Length and mass data had been collected by the *Kaiyo Maru* when working in Subarea 48.3. No other length mass data from the survey were available to the workshop.

3.39 These data from the CCAMLR-2000 Survey were examined in relation to other published krill length to mass data from Area 48 which were thought to be compatible in terms of the season and krill maturity stage composition. The following length to mass relationships were considered.

a	b	L (mm)	Source
0.000925	3.550	-	FIBEX 1
0.00180	3.383	-	FIBEX 2
0.002236	3.314	30–48	This survey *Kaiyo Maru*
0.00385	3.20	26–59	Morris et al. (1988)
0.00205	3.325	23–60	Siegel (1992)

3.40 SC-CAMLR (SC-CAMLR-X, paragraph 3.34) adopted the following krill TS to length relationship at 120 kHz:

$$TS_{120} = -127.45 + 34.85 \log (L) \quad (4)$$

3.41 Applying the frequency dependent formula given by Greene et al. (1991) the following formulae for 38 and 200 kHz are obtained:

$$TS_{38} = -132.44 + 34.85 \log (L) \quad (5)$$

$$TS_{200} = -125.23 + 34.85 \log (L) \quad (6)$$

3.42 The workshop did not have sufficient time to examine *in situ* TS data from the survey. Consequently equations 4, 5 and 6 had been used to estimate the TS of the krill in the survey area. The workshop encouraged further work to compare the *in situ* results from the survey with those from the equations (see paragraph 6.7).

3.43 Substituting equation 3 along with equation 4, 5 and 6 as appropriate into equation 2, conversion factors were calculated to convert S_A (m^2/n $mile^2$) to areal biomass krill density (g/m^2).

3.44 The workshop agreed to use the conversion factor derived from the length and mass data obtained aboard the *Kaiyo Maru* because these data were collected during the CCAMLR-2000 Survey. The values fall within the range of the other estimates in Table 21.

Depth of Integration

3.45 The workshop had no prior reason for selecting any specific depth to set the lower level of integration. After some discussion it was agreed to integrate down to the deepest sampling depth and to describe the detection thresholds which will be a function of krill density and noise level (signal to noise ratios) for each frequency.

Examination of Echograms

3.46 The workshop considered ways by which the filtered resampled noise-free echograms (see paragraph 3.32) might be examined to identify outlying and erroneous values. This was tasked to four subgroups, one for each vessel. Noise subtraction was checked by inspection of raw echograms and filtered resampled noise-free echograms. Outlying and erroneous values were checked by integrating and inspecting the output by cell in Microsoft Excel.

3.47 In order to ensure consistency in the integration analysis a cross-checking process was included as follows:

Dataset	Analysed by
Kaiyo Maru	Drs S. Kasatkina and A. Malyshko (Russia)
Atlantida	Dr S. Kawaguchi and Mr Y. Takao (Japan)
James Clark Ross	Mrs J. Emery (USA)
Yuzhmorgeologiya	Drs J. Watkins and A. Brierley and Ms C. Goss (UK)

3.48 The integration analysis was undertaken according to the following schedule:

Step One: The 120 kHz echogram was examined and edited to ensure that near-surface swarms were included and bubbles arising from surface turbulence excluded. For this process the display threshold was set to -70 dB and depth grid turned 'off'. The resulting edited surface layer definition was saved.

Step Two: The S_v threshold was set to -100 dB and with this setting the noise level on NOISE 120 file was adjusted until the 'rainbow' was removed. The adjusted noise level was increased by 3 dB and the file resaved. All changes were recorded (Table 7).

Step Three: In the EV file menu properties the following variables were selected: S_v mean, S_A mean, S_v max, C height, C depth, Date M, Time M, Lat S, Lon S, Lat E, Lon E, Lat M, Lon M and EV file name. (The naming convention for these variables is M = mean, S = start, E = end). The filtered resampled noise-free echogram at 120 kHz was opened and the grid changed to a GPS distance of 1 n mile and 5 m depth. The echogram was then integrated by cell and the resultant integrated file saved according to the following filename convention: 'transect name' 'freq.' (eg SS03_120.csv). These files were saved to a folder for each ship.

Step Four: Each file was sorted by S_v max. This allowed the highest values to be identified by date, time and depth bin. These high values were then examined on the echogram to determine whether they were likely to have been due to biological scatterers such as krill or else due to noise, bottom integration or some other extraneous scattering. Scatterers thought not to be krill were labelled as 'bad data'. The corrected echogram was then re-integrated and saved as described in Step Three above.

3.49 The 38 and 200 kHz echograms were then analysed using the same process for noise subtraction and integration but excluding the 'bad data' regions and including near surface swarms identified at 120 kHz.

3.50 Conversion factors, CCAMLR-2000 from Table 21, were used to convert S_A along each transect to biomass using the appropriate clusters as indicated in Table 6.

3.51 For several reasons ships deviated from the planned transects. Such deviations included random effects caused by strong winds and ocean currents, and larger systematic deviations caused by avoidance of icebergs. To correct for these larger deviations, an expected change in latitude per nautical mile of transect, Δlat was calculated from the waypoints derived in WG-EMM-99/7. These values are listed in Table 22. Although the transects, on great circle courses, did not have a constant heading, using a constant Δlat as shown in Table 22 introduces a possible error of only 9 m in a N–S transect, and a possible error of only 25 m in a NE–SW transects. These errors are within the expected accuracy of the available navigation. An actual latitude made good, $\Delta l\hat{a}t$, was derived by differencing the latitudes of the 1 n mile Echoview output. An interval weighting W_I was calculated as:

$$W_{\mathrm{I}} = \frac{|\Delta lat| - |(\Delta lat - \Delta l\hat{a}t)|}{|\Delta lat|} \tag{7}$$

If the deviation from the standard track line for a particular interval was greater than 10% (i.e. if $W_I < 0.9$), then the 1 n mile integral was scaled by W_I, otherwise $W_I = 1$.

3.52 The sum of the interval weightings along each transect was used to weight the transect means to provide a stratum biomass.

3.53 The planned transect lengths within each subarea are set out in Table 23 and it was agreed that these should be used to estimate the proportion of survey effort in each subarea.

RESULTS

Estimated Standing Stock

4.1 Mean krill biomass densities along each transect and at each acoustic frequency were calculated according to the schedule set out in paragraphs 3.48 to 3.52. Biomass estimates were made according to the method of Jolly and Hampton (1990) as agreed in paragraph 3.1. The results are set out in Tables 24 to 26 and Figure 7.

4.2 With the results to hand, a series of checks was made to determine as far as possible that the analyses had been undertaken in the prescribed way.

4.3 In theory there should be the same number of distance intervals at each frequency for each transect. In some instances, however, there were differences, and in these instances files were checked and corrected.

4.4 As a first step to investigate the possibility of bias between ships, an analysis of variance was used to test whether there were significant differences between vessels. A rigorous test could only be undertaken for the Scotia Sea and Antarctic Peninsula regions where the survey tracks of the individual vessels, *James Clark Ross*, *Kaiyo Maru* and *Yuzhmorgeologiya*, were interleaved. The results from this analysis are set out in Table 27 and indicate there to be no significant difference between vessels. A second ANOVA which included the results from the *Atlantida*, the only vessel to sample in the South Sandwich Islands area, also indicated that there was no significant difference between any of the vessels (Table 28).

4.5 The distribution of the W_I (paragraph 3.51) was plotted on a map of the surveyed area to indicate whether any bias might exist in the sampling intensity. Although statistical analyses were not possible in the time available, a visual examination of the results suggested that the distribution was not likely to affect the estimates of krill density.

4.6. The distribution of the conversion factors along the transects of the krill length-frequency clusters was checked against the nominal distribution in Table 6. The distribution was confirmed to be correct over nearly all transects except within the region of the South Shetland Islands mesoscale survey on transects AP15 and AP16 where short portions of these two transects were assigned to Cluster 2 instead of Cluster 3. The workshop noted that the potential error to the standing stock estimate arising from this was likely to negligible. It was agreed that no further action was necessary at the workshop.

4.7 The krill standing stock, estimated using 120 kHz as agreed by the workshop, was 44.29 million tonnes (CV 11.38%). The standing stock estimates at the other two frequencies were 29.41 million tonnes (CV 9.25%) at 38 kHz and 44.82 million tonnes (CV 15.76%) at 200 kHz (see Tables 24 to 26; Figure 7).

4.8 The workshop accepted the estimate of krill standing stock at 120 kHz (44.29 million tonnes) as the best available for the CCAMLR-2000 Survey.

Considerations of Uncertainty

4.9 The workshop noted that the estimation of standing stock by the Jolly and Hampton method gave an associated sampling variance for the survey. This sampling variance provides an important component of the uncertainty. There are however other components of uncertainty which need to be identified so that they can be incorporated into the estimation of γ for the GYM.

4.10 During the meeting Dr Demer had undertaken a series of analyses to quantify the following components of uncertainty which might make a significant contribution to the overall uncertainty:

(i) TS: dependence on acoustic frequency and krill size and orientation;
(ii) detection probability: background noise, distribution of TS, krill by depth; and
(iii) efficiency of krill detection and delineation.

4.11 The following topics were thought to have a minimal effect on the overall uncertainty: variation in α and sound speed over the survey area in comparison to the agreed default values.

4.12 In order to provide an estimate of combined measurement and sampling uncertainty, it is necessary to undertake further analyses of the data and undertake simulation studies to determine the extent and relative importance of the key components. There was insufficient time at the workshop to undertake these studies. Dr Demer offered to develop this analysis and provide a paper for consideration at WG-EMM-2000.

ARCHIVE AND STORAGE OF DATA ANALYSED AT THE WORKSHOP

5.1 The analyses by the workshop were based on the three core datasets collected during the CCAMLR-2000 Survey (SC-CAMLR-XVIII, Annex 4, Appendix D, paragraph 19): acoustic data, micronekton net data, and CTD profiles. These data are to be transferred, together with documentation, to a new CCAMLR database for archiving. Dr D. Ramm (Data Manager) will present a report on the archiving process to WG EMM-2000.

5.2 Four types of acoustic data files were used: raw ping-by-ping data (EK5 files); Echoview data annotation files (EV files); S_A by transect and frequency, and total S_A by frequency (CSV files); and biomass by stratum (Excel files).

5.3 The raw ping-by-ping data files consist of EK500 telegrams, and these files are in a format specified by SonarData. Raw data were available from the *Atlantida* (3 414 files, 4.40 Gb); *James Clark Ross* (1 499 files, 5.88 Gb); *Kaiyo Maru* (936 files; 4.17 Gb); *Yuzhmorgeologiya* (1 445 files, 6.54 Gb). Dr Hewitt agreed to submit the EK500 data on CD-ROM (approximately 40 disks) to the Secretariat by the end of August 2000, together with a copy of the relevant documentation describing the data format used in these files.

5.4 The EV files specify the EK5 data, transect regions and acoustic parameters used in the analyses done in Echoview. These files are in Echoview format, and there is one EV file for each transect. The values of parameters are summarised in the tables of this report. The specifications held in each file are presently only accessible using Echoview, and the Secretariat does not have this software. Dr Hewitt agreed to submit the EV files to the Secretariat by the end of August 2000. In addition, the group agreed that a detailed listing of the data held in the EV files be developed by the Secretariat in consultation with Dr Hewitt and Mr Higginbottom.

5.5 The S_A files, in CSV format, and the biomass by stratum files, in Microsoft Excel, were developed at the workshop. Dr Hewitt agreed to submit the CSV files, Excel files and their descriptions to the Secretariat by the end of August 2000.

5.6 The micronekton net data were derived from samples collected using the RMT8. Raw data had been collated and analysed by Dr Siegel prior to the workshop (WG-EMM-00/6). Dr Siegel advised that these data required some further validation, and he agreed to do this shortly after the workshop. Once validated, Dr Siegel agreed to submit the micronekton net data, together with data documentation, to the Secretariat by early July 2000.

5.7 The CTD data were collected by all four ships. Data from the *James Clark Ross, Kaiyo Maru* and *Yuzhmorgeologiya* had been collated and analysed by Dr Brandon prior to the workshop. The data from the *Kaiyo Maru* required minor re-calibration, and Dr Naganobu agreed to undertake this task, and resubmit the data to Dr Brandon as soon as possible. In addition, Dr Kasatkina agreed to submit the CTD data from the *Atlantida* to Dr Brandon by early July 2000. Dr Brandon would then collate the CTD data, and submit these data, together with relevant documentation, to the Secretariat.

5.8 All acoustic data submitted to the Secretariat will initially be stored on CD-ROM. A catalogue of these data, together with the RMT8 and CTD data will be held in a Microsoft Access database. Once the structure of the new CCAMLR-2000 Survey database is established, data will be transferred to SQL Server format, in line with other data held by the Secretariat. Resources should be provided to the Secretariat so that the acoustic data can be transferred from CD-ROM to hard disk within the next 12 months. This will ensure that these data are backed up to magnetic tape regularly, and can be transferred, along with all other CCAMLR data, to any new, future system. All survey data submitted to CCAMLR will be subject to the rules of access and use of CCAMLR data.

FUTURE WORK

Archiving of Data and Access to Samples

6.1 All data considered by the workshop, together with detailed documentation of all data fields, are to be submitted to the CCAMLR Data Centre for archiving as specified in paragraphs 5.3 (EK5 files); 5.4 (EV files); 5.5 (S_A files), 5.6 (RMT8 data) and 5.7 (CTD data). A report on the archiving process will be presented to WG-EMM-2000 (paragraph 5.1).

6.2 The group noted that the archiving of the CCAMLR-2000 Survey data has a budgetary consideration: additional hard disk space and back-up capacity within the Secretariat will be required to ensure that all EK5 files can be transferred from CD-ROM format within the next 12 months (paragraph 5.8). To ensure complete archiving of the workshop data and analysis results, the Secretariat should hold a copy of Echoview 2.00.

6.3 All survey data submitted to CCAMLR will be subject to the rules of access and use of CCAMLR data (paragraph 5.8).

6.4 The group identified the need to develop a protocol and process for scientists wishing to access zooplankton and nekton samples collected using the RMT1 and RMT8 nets (Attachment C).

Publications and Future Symposia and Workshops

6.5 Much of the CCAMLR-2000 Survey data collected is yet to be analysed. It is expected that each major set of data would form the focus of future CCAMLR workshops. Data analysed at such workshops will need to be transferred to the CCAMLR Data Centre for archiving. All data submitted to the CCAMLR Data Centre for archiving should be fully documented with specific data formats being defined.

6.6 The following possibilities were identified for the future publication of the CCAMLR-2000 Survey results:

(i) prepare a short communication (in the order of 1 000 words) to a scientific journal with broad readership under the following conditions:

  (a) such communication will describe the survey, the participants, the methods of data collection and analysis and the estimate of B_0, but not necessarily the implications;

  (b) such communication will be authored by a team name such as ‘CCAMLR-2000 Survey Team’ with team members listed in alphabetical order in a footnote;

  (c) an initial draft will be prepared within the next four months by Dr Hewitt and circulated for comments via email.

(ii) develop a series of papers to describe the results of, and the protocols developed by, the workshop. This could include the development of a special issue of *CCAMLR Science*.

(iii) consolidate the protocols of the CCAMLR-2000 Survey into a CCAMLR manual on the execution of acoustic surveys of krill.

6.7 The CCAMLR-2000 Survey has produced a unique multinational dataset. It was agreed that to maximise the potential of these data, their collaborative analyses should be encouraged. Such analyses could be undertaken by future CCAMLR workshops, and/or through collaboration between individual data providers as well as between individual scientists. This requires that the intellectual property rights attached to the data are recognised and balanced with the need to maximise data use. Again, all data analysed at CCAMLR workshops will be subject to the CCAMLR data access rules. In responding to requests for other data, the SICs (or their alternates) should serve as a first contact point to manage data access and as a conduit to promote collaborative analyses. WG-EMM and the Scientific Committee were requested to consider this matter further.

6.8 Future analyses identified by the workshop include, *inter alia*:

(i) Sampling techniques:

(a) apply alternative analyses to the current survey data (e.g. using geostatistical techniques to estimate mean krill biomass density and its variance over the survey area);

(b) refine krill density and biomass estimates using conversion factors derived from data collected by all ships during the survey;

(c) develop refined methods for acoustic target delineation;

(d) identify targets larger than krill, especially myctophids;

(e) compare *in situ* TS estimates with those from SC-CAMLR equations;

(f) investigate *in situ* TS measurements with respect to the biological condition of krill;

(g) determine the pattern of ambient noise from 38 kHz in relation to water depth and weather;

(h) investigate net sampling survey design, net selection, catchability and selectivity with respect to krill; and

(i) develop protocols for the application of optimal temporal and spatial designs for future acoustic surveys of krill.

(ii) Multidisciplinary analyses:

(a) investigate the distribution of krill density and classification (length and maturity) in respect to water masses and in relation to the cluster boundaries identified by the workshop;

(b) investigate the distribution of acoustic scatterers and zooplankton other than krill;

(c) investigate the spatial distribution of krill biomass with respect to latitude, water masses and bathymetry;

(d) analyse combined oceanographic datasets;

(e) determine flow fields across the Scotia Sea and then calculate krill flux;

(f) compare acoustic data from mesoscale survey boxes with acoustic survey results from similar boxes over time;

(g) compare krill standing stock estimate to validate land-based dependent species population estimates; and

(h) integrate CCAMLR-2000 Survey data collected by CCAMLR and the IWC.

CLOSE OF WORKSHOP

7.1 The report of the workshop was adopted.

7.2 The Chairman of the Scientific Committee, Dr D. Miller, thanked Dr Hewitt for convening a very successful workshop and the US Government for facilitating the process. The workshop joined Dr Everson in thanking Mrs L. Bleathman and Dr Ramm for their participation and support. Dr Hewitt then thanked Dr Everson for his major input as rapporteur, and thanked contributors for their valued input to discussions and the report, and for working long hours to ensure the success of the workshop.

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Watkins, J.L. and A.S. Brierley. 2000. Verification of acoustic techniques used to identify Antarctic krill. *ICES J. Mar. Sci.*, (in press).

LIST OF DOCUMENTS

WG-EMM-00/06	Krill distribution patterns in the Atlantic sector of the Antarctic during the CCAMLR-2000 Survey V. Siegel, S. Kawaguchi, F. Litvinov, V. Loeb and J. Watkins

Table 1: Transect section from CCAMLR-2000 Survey large-scale transects which lie within mesoscale survey boxes. (See Table 4 for transect abbreviations).

Transect	From		To	
	Latitude (°S)	Longitude (°W)	Latitude (°S)	Longitude (°W)
South Georgia				
SS03	53.7099	35.2440	54.6058	35.1363
SS04	53.1002	37.1962	53.9972	37.1336
South Orkneys				
SS07	59.8292	43.4326	60.7249	43.5246
SS08	59.7697	45.2811	60.6639	45.4222
South Shetlands				
AP13	60.4858	55.4738	61.2918	54.6604
AP14	61.0372	57.9057	61.8577	57.1422
AP15	61.4720	60.2064	62.3050	59.4948
AP16	61.6936	61.8532	62.5341	61.0074
South Sandwich				
SSb	59.7557	25.3475	55.3544	27.0268
Overlap between AP and SS*				
SS10	61.9923	50.0037	discard data to the south	

* This portion of SS10 was discarded because of an overlap between AP and SS.

Table 2: System-specific echosounder settings by ship.

Transceiver	Menu	*Atlantida*	*James Clark Ross*	*Kaiyo Maru*	*Yuzhmorgeologiya*
1	Transducer type	ES38B	ES38B	ES38B	ES38-12
	Transducer depth (m)	5.0	5.70	5.8	7.0
	Two-way beam angle (dB)	-21.2	-20.8	-20.9	-15.9
	S_v transducer gain (dB)	23.32	25.49	27.06	22.95
	TS transducer gain (dB)	23.50	25.60	27.32	22.51
	Angle sens. along	21.9	21.9	21.9	12.5
	Angle sens. athw.	21.9	21.9	21.9	12.5
	3 dB beamw. along (°)	7.1	7.0	6.8	12.2
	3 dB beamw. athw. (°)	7.1	7.1	6.9	12.2
2	Transducer type	ES120-7	ES120	ES120-7	ES120-7
	Transducer depth (m)	5.0	5.70	5.8	7.0
	Two-way beam angle (dB)	-20.9	-18.4	-20.6	-20.4
	S_v transducer gain (dB)	24.49	2026	24.74	24.52
	TS transducer gain (dB)	24.66	20.26	24.83	24.13
	Angle sens. along	15.7	15.7	21.0	21.0
	Angle sens. athw.	15.7	15.7	21.0	21.0
	3 dB beamw. along (°)	7.3	9.3	7.1	7.3
	3 dB beamw. athw. (°)	7.3	9.3	7.1	7.3
3	Transducer type	200_28	200_28	200_28	200_28
	Transducer depth (m)	5.0	5.70	5.8	7.0
	Two-way beam angle (dB)	-20.3	-20.8	-20.5	-20.5
	S_v transducer gain (dB)	23.26	22.78	25.76	26.30
	TS transducer gain (dB)	23.47	23.07	25.78	26.30
	3 dB beamw. along (°)	7.1	6.9	7.1	7.1
	3 dB beamw. athw. (°)	7.1	7.1	7.1	7.1

Table 3: Survey echosounder settings defined in protocol.

Operation menu		Ping mode	Normal
		Ping auto start	Off
		Ping interval	2.0 Sec
		Transmit power	Normal
		Noise margin	0 dB
Transceiver menu	Transceiver-1 menu	Mode	Active
		Transd. Sequence	Off
		Absorption coef.	10 dB/km
		Pulse length	Medium
		Bandwidth	Wide
		Max. Power	2000 W
		Alongship offset	0.00°
		Athw.ship offset	0.00°
	Transceiver-2 menu	Mode	Active
		Transd. sequence	Off
		Absorption coef.	26 dB/km
		Pulse length	Long
		Bandwidth	Narrow
		Max. power	1000 W
		Alongship offset	0.00°
		Athw.ship offset	0.00°
	Transceiver-3 menu	Mode	Active
		Transd. sequence	Off
		Absorption coef.	40 dB/km
		Pulse length	Long
		Bandwidth	Narrow
		Max. power	1000 W
		Alongship offset	0.00°
		Athw.ship offset	0.00°
Bottom detection menu*	Bottom detection-1 menu	Min. depth	10.0 m
		Max. depth	500 m
		Min. depth alarm	0.0 m
		Max. depth alarm	0.0 m
		Bottom lost al.	0.0 m
		Min. level	-50 dB
	Bottom detection-2 menu	Min. depth	10.0 m
		Max. depth	500 m
		Min. depth alarm	0.0 m
		Max. depth alarm	0.0 m
		Bottom lost al.	0.0 m
		Min. level	-50 dB
	Bottom detection-3 menu	Min. depth	10.0 m
		Max. depth	500 m
		Min. depth alarm	0.0 m
		Max. depth alarm	0.0 m
		Bottom lost al.	0.0 m
		Min. level	-50 dB
Log menu		Mode	Speed
		Ping interval	20
		Time interval	20 s
		Dist. interval	1.0 n mile
		Pulse rate per n mile	200

* Initial settings, changed according to conditions.

continued

Table 3 (continued)

Layer menu		Super layer	Ship specific
	Layer-1 menu	Type	Ship specific
	Layer-2 menu	Type	Ship specific
	Layer-3 menu	Type	Ship specific
	Layer-4 menu	Type	Ship specific
	Layer-5 menu	Type	Ship specific
	Layer-6 menu	Type	Ship specific
	Layer-7 menu	Type	Ship specific
	Layer-8 menu	Type	Ship specific
	Layer-9 menu	Type	Ship specific
	Layer-10 menu	Type	Ship specific
TS detection menu	TS Detection-1 menu	Min. value	-90 dB
		Min. echo length	0.8
		Max. echo length	2.5
		Max. gain comp.	4.0 dB
		Max. phase dev.	2.0
	TS Detection-2 menu	Min. value	-90 dB
		Min. echo length	0.8
		Max. echo length	2.5
		Max. gain comp.	4.0 dB
		Max. phase dev.	2.0
	TS Detection-3 menu	Min. value	-90 dB
		Min. echo length	0.8
		Max. echo length	2.5
		Max. gain comp.	4.0 dB
		Max. phase dev.	2.0
Ethernet com. menu	Telegram menu	Remote control	On
		Sample range	0 m
		Status	On
		Parameter	On
		Annotation	Off
		Sound velocity	Off
		Navigation	On
		Motion sensor	Off
		Depth	1
		Depth nmea	Off
		Echogram	1&2&3
		Echo-trace	1&2&3
		S_v	Off
		Sample angle	Off
		Sample power	Off
		Sample S_v	Off
		Sample TS	Off
		Vessel-log	On
		Layer	On
		Integrator	Off
		Ts distribution	Off
		Towed fish	Off
	UDP port menu	Status	Ship specific
		Parameter	Ship specific
		Annotation	Ship specific
		Sound velocity	Ship specific
		Navigation	Ship specific
		Motion sensor	Ship specific

continued

Table 3 (continued)

Ethernet com. menu (continued)	UDP port menu	Depth	Ship specific
		Echogram	Ship specific
		Echo-trace	Ship specific
		S_v	Ship specific
		Sample angle	Ship specific
		Sample power	Ship specific
		Sample S_v	Ship specific
		Sample TS	Ship specific
		Vessel-log	Ship specific
		Layer	Ship specific
		Integrator	Ship specific
		TS distribution	Ship specific
		Towed fish	Ship specific
	Echogram-1 menu	Range	500 m
		Range start	0 m
		Auto range	Off
		Bottom range	0 m
		Botttom range start	10 m
		No. of main val.	700
		No. of bot. val.	0
		TVG	20 log r
	Echogram-2 menu	Range	500 m
		Range start	0 m
		Auto range	Off
		Bottom range	0 m
		Bottom range start	10 m
		No. of main val.	700
		No. of bot. val.	0
		TVG	20 log r
	Echogram-3 menu	Range	500 m
		Range start	0 m
		Auto range	Off
		Bottom range	0 m
		Bottom range start	10 m
		No. of main val.	700
		No. of bot. val.	0
		TVG	20 log r
Serial com. menu	Telegram menu	Format	ASCII
		Modem control	Off
		Remote control	On
		Status	Off
		Parameter	Off / on
		Annotation	Off / on
		Navigation	Off
		Sound velocity	Off
		Motion sensor	Off
		Depth	Off
		Depth nmea	Off
		Echogram	Off
		Echo-trace	Off
		S_v	Off
		Vessel-log	Off
		Layer	Off
		Integrator	Off

continued

Table 3 (continued)

Serial com. menu (continued)	Telegram menu	TS distribution	Off
		Towed fish	Off
	USART menu	Baudrate	9600
		Bits per char.	8
		Stop bits	1
		Parity	None
Motion sensor menu		Heave	Off
		Roll	Off
		Pitch	Off
Utility menu		Beeper	Off / On
		Status messages	On
		Rd display	Off
		Fifo output	Off
		External clock	Off
		Default setting	No
		Language	English

Table 4: Summary of activities undertaken by vessels during the CCAMLR-2000 Survey (January–February 2000), and data submitted to the B_0 Workshop. AP – Antarctic Peninsula; Sand – South Sandwich Islands; SG – South Georgia; SOI – South Orkney Islands; SS – Scotia Sea; SSI – South Shetland Islands.

	Vessel			
	Atlantida	*Kaiyo Maru*	*James Clark Ross*	*Yuzhmorgeologiya*
Synoptic survey				
Survey area	SS	AP SS	AP SS	AP SS
CCAMLR subareas	48.4	48.1 48.2 48.3	48.1 48.2 48.3	48.1 48.2 48.3
Start date	17 January	11 January	18 January	13 January
End date	1 February	2 February	10 February	4 February
Large-scale transects				
Number	3	6	7	6
Transect names	SSa SSb SSc	SS03 SS06 SS09 AP12 AP15 AP18	AP13 AP16 AP19 SS01 SS04 SS07 SS10	AP11 AP14 AP17 SS02 SS05 SS08
Mesoscale transects				
Number	10	8	0	8
Transect names	Sand01-10	SSI01-08		SG01-04 SOI01-04
Calibration				
Pre-survey				
Date	14 January	9 January	16 January	12 January
Location	Stromness Bay	Stromness Bay	Stromness Bay	Stromness Bay
Post-survey				
Date	5 February	4 February	11 February	7 March
Location	Stromness Bay	Admiralty Bay	Admiralty Bay	Admiralty Bay
Data submitted				
Acoustic data	√	√	√	√
Net data	√	√	√	√
CTD data		√	√	√

Table 5: Summary of data collected by vessels during the CCAMLR-2000 Survey. ADCP – acoustic Doppler current profiler; CPR – continuous plankton recorder; CTD – conductivity temperature depth probe; EPCS – electronic plankton counting system; EK500 – Simrad EK-500 echosounder (38, 120, 200 kHz) with SonarData Echoview software; IWC – IWC Observers; JNCC – Joint Nature Conservancy Council Seabirds-at-Sea; LADCP – lowered ADCP; MAPT – meteorological automatic picture transmission; NORPAC – North Pacific standard net; RMT1 – rectangular midwater trawl 1 m^2; RMT8 – rectangular midwatertrawl 8 m^2; SeaWIFS – sea-viewing wide field-of-view sensor; XBT – expendable bathythermograph; XCTD – expendable CTD.

Type of Data	Vessel			
	Atlantida	*Kaiyo Maru*	*James Clark Ross*	*Yuzhmorgeologiya*
Under-way Observations:				
Acoustic survey				
Acoustic profiles*	EK500	EK500	EK500	EK500
Bathymetry			EA500 (12kHz)	
Physical oceanography				
Meteorological data	Instruments	MAPT	Instruments	Instruments
Satellite images		NOAA		SeaWIFS
Current velocity and direction	ADCP		ADCP	
Water temperature and salinity		EPCS, XBT, XCTD	@6m	Thermosalinograph
Biological sampling				
Chlorophyll and zooplankton		EPCS		Flurometer
Chlorophyll calibration	Water samples	Water samples	Water samples	Water samples
Predator observations				
Seabirds and marine mammals	Observers	IWC, Observers	IWC, JNCC	IWC
On-Station Sampling:				
Physical oceanography				
Temperature and conductivity*	CTD	CTD	CTD	CTD
Dissolved oxygen	CTD	CTD		CTD
Current velocity and direction		LADCP	ADCP	
Water samples	to 1 000 m	to 1 000 m		to 1 000 m
Biological sampling				
Krill and other micronekton*	RMT8	RMT8	RMT8	RMT8
Zooplankton	RMT1	RMT1, NORPAC, CPR	RMT1, Bongo	RMT1
Chlorophyll-*a*		√		√
Nutrients		√		

* Core datasets

Table 6: Latitudinal position at which krill size clusters change along acoustic transects. (See Table 4 for transect abbreviations and Figure 4 for a description of the clusters).

Transect	Cluster	Position (latitude S) between Clusters
SS01	2	North of 54°30’
SS01	1	South of 54°30’
SS02	2	North of 52°54’
SS02	1	52°54’ to 58°18’
SS02	2	58°18’ to 60°
SS02	1	South of 60°
SS03	2	North of 53°
SS03	1	53° to 57°30’
SS03	2	57°30’ to 59°21’
SS03	1	South of 59°21’
SS04 to SS06	2	Entire transect
SS07	2	North of 60°
SS07	3	South of 60°
SS08	2	North of 60°
SS08	3	60° to 61°
SS08	2	South of 61°
SS09	2	South of 62°15’
SS09	3	North of 62°15’
SS10	2	South of 61°15’
SS10	3	North of 61°15’
AP11 to AP16*	2	South of 61°15’
AP11 to AP16*	3	North of 61°15’
AP17 to AP19	3	Entire transect
All SOI	3	Entire transect
SSI01	3	North of 61°20’
SSI01	2	South of 61°20’
SSI02 and 03	3	North of 61°30’
SSI02 and 03	2	South of 61°30’
SSI04 and 05	3	North of 61°45’
SSI04 and 05	2	South of 61°45’
SSI06 and 07	3	North of 62°
SSI06 and 07	2	South of 62°
SSI08	3	Entire transect
SG01 to 03	1	Entire transect
SG04	2	Entire transect
SSa 48.4 east	2	North of 58°45’
SSa 48.4 east	1	South of 58°45’
SSb 48.4 middle	2	North of 58°
SSb 48.4 middle	1	South of 58°
SSc 48.4 west	2	North of 56°33’
SSc 48.4 west	1	56°33’ to 58°
SSc 48.4 West	2	58° to 59°05’
SSc 48.4 West	1	South of 59°05’
Sand 01,02,03,06,07	2	Entire transect
Sand 04,05,08,09,10	1	Entire transect

* During the error checking phase (paragraph 4.6) it was noted that portions of AP15 and AP16 north of the mesoscale box in the SSI were incorrectly assigned to Cluster 2 and should have been assigned to Cluster 3.

Table 7: CCAMLR-2000 Survey noise measurements (dB) and surface exclusion. Atl – *Atlantida;* JCR – *James Clark Ross*; KyM – *Kaiyo Maru*; Yuz – *Yuzhmorgeologiya.* (See Table 4 for transect abbreviations).

Ship	Transect	Surface Layer (m)	Noise (S_v re 1 m)		
			38 kHz	120 kHz	200 kHz
Yuz	SG01	20	-123.00	-123.00	-123.00
Yuz	SG02	20	-124.00	-120.00	-121.00
Yuz	SG03	20	-125.00	-124.00	-124.00
Yuz	SG04	15	-137.00	-129.00	-124.00
Yuz	SS02	20	-137.00	-123.00	-124.00
Yuz	SS05	15	-135.00	-125.00	-123.00
Yuz	SS08	15	-131.00	-125.00	-123.00
Yuz	SOI01	15	-126.00	-120.00	-119.00
Yuz	SOI02	15	-126.00	-122.00	-123.00
Yuz	SOI03	15	-129.00	-122.00	-122.00
Yuz	SOI04	20	-135.00	-127.00	-122.00
Yuz	AP11	20	-129.00	-120.00	-123.00
Yuz	AP14	15	-129.00	-120.00	-125.00
Yuz	AP17	20	-121.00	-120.00	-117.00
Atl	Sand01	15	-127.00	-136.50	-135.00
Atl	Sand02	15	-127.00	-136.50	-135.00
Atl	Sand03	15	-127.00	-136.50	-135.00
Atl	Sand04	15	-127.00	-136.50	-135.00
Atl	Sand05	15	-127.00	-136.50	-135.00
Atl	Sand06	15	-127.00	-136.50	-135.00
Atl	Sand07	15	-127.00	-136.50	-135.00
Atl	Sand08	15	-127.00	-136.50	-135.00
Atl	Sand09	15	-127.00	-136.50	-135.00
Atl	Sand10	15	-127.00	-136.50	-135.00
Atl	SSa	15	-127.00	-136.50	-135.00
Atl	SSb	15	-127.00	-136.50	-135.00
Atl	SSc	15	-127.00	-136.50	-135.00
JCR	SS01	20	-150.00	-124.00	-110.00
JCR	SS04	15	-150.00	-124.00	-112.00
JCR	SS07	20	-150.00	-124.00	-112.00
JCR	SS10	20	-150.00	-124.00	-110.00
JCR	AP13	20	-150.00	-124.00	-110.00
JCR	AP16	20	-150.00	-124.00	-110.00
JCR	AP19	20	-152.00	-124.00	-110.00
KyM	SS03	20	-136.40	-136.40	-134.40
KyM	SS06	20	-147.40	-136.40	-138.10
KyM	SS09	20	-141.90	-136.80	-138.40
KyM	AP12	20	-147.00	-135.70	-135.10
KyM	AP15	20	-148.10	-136.20	-136.10
KyM	AP18	20	-147.40	-136.60	-136.80
KyM	SSI01	20	-140.90	-136.60	-134.40
KyM	SSI02	20	-138.90	-136.60	-133.40
KyM	SSI03	20	-144.90	-136.60	-133.40
KyM	SSI04	20	-141.90	-136.60	-135.40
KyM	SSI05	20	-144.90	-136.60	-134.40
KyM	SSI06	20	-146.90	-136.60	-135.40
KyM	SSI07	20	-149.90	-136.60	-135.40
KyM	SSI08	20	-152.90	-136.60	-135.40

Table 8: Calibration constants S_v gain (dB).

Frequency	Vessel	First Calibration	Second Calibration	Chosen Value
38 kHz	*Atlantida*	23.42	23.32	23.32
	James Clark Ross	25.49	25.53	25.51
	Kaiyo Maru	27.06	27.09	27.06
	Yuzhmorgeologiya	22.43	22.29	22.36
120 kHz	*Atlantida*	23.23	24.49	24.49
	James Clark Ross	20.26	20.15	20.20
	Kaiyo Maru	24.74	24.30	24.74
	Yuzhmorgeologiya	25.37	25.16	25.26
200 kHz	*Atlantida*	24.83	23.26	23.26
	James Clark Ross	22.78	23.04	22.91
	Kaiyo Maru	25.76	25.74	25.76
	Yuzhmorgeologiya	26.12	25.80	25.96

Table 9: Calibration constants TS gain (dB).

Frequency	Vessel	First Calibration	Second Calibration	Chosen Value
38 kHz	*Atlantida*	23.76	23.50	23.50
	James Clark Ross	25.60	25.60	25.60
	Kaiyo Maru	27.32	27.35	27.32
	Yuzhmorgeologiya	22.64	22.37	22.51
120 kHz	*Atlantida*	23.29	24.66	24.66
	James Clark Ross	20.26	20.09	20.18
	Kaiyo Maru	24.83	24.55	24.83
	Yuzhmorgeologiya	25.56	25.17	25.37
200 kHz	*Atlantida*	24.50	23.47	23.47
	James Clark Ross	23.07	23.16	23.12
	Kaiyo Maru	25.78	25.77	25.78
	Yuzhmorgeologiya	26.12	25.80	25.96

Table 10: CCAMLR-2000 Survey calibration settings.

Atlantida	38 kHz		120 kHz		200 kHz	
	Logging	Processing	Logging	Processing	Logging	Processing
Absorption coef. (dB/m)	0.010000	0.010000	0.026000	0.028000	0.040000	0.041000
Sound speed (m/s)	1449.00	1456.00	1449.00	1456.00	1449.00	1456.00
Transmitted power (W)	2000.00	2000.00	1000.00	1000.00	1000.00	1000.00
2-way beam angle (dB)	-21.30	-21.30	-21.00	-21.00	-20.30	-20.30
S_V gain (dB)	23.43	23.32	23.23	24.49	24.83	23.26
Wavelength (m)	0.03868	0.03844	0.01225	0.01223	0.00735	0.00728
Trans. pulse length (ms)	1.000	1.000	1.000	1.000	1.000	1.000
Frequency (kHz)		38.00		120.00		200.00
Draft correction (m)		0.00		0.00		0.00
Nominal angle (°)		7.10		7.30		7.10

James Clark Ross	38 kHz		120 kHz		200 kHz	
	Logging	Processing	Logging	Processing	Logging	Processing
Absorption coef. (dB/m)	0.010000	0.010000	0.026000	0.028000	0.040000	0.041000
Sound speed (m/s)	1449.00	1456.00	1449.00	1456.00	1449.00	1456.00
Transmitted power (W)	2000.00	2000.00	1000.00	1000.00	1000.00	1000.00
2-way beam angle (dB)	-20.80	-20.80	-18.40	-18.40	-20.80	-20.80
S_V gain (dB)	25.49	25.51	20.26	20.20	22.78	22.91
Wavelength (m)	0.03868	0.03844	0.01225	0.01223	0.00735	0.00728
Trans. pulse length (ms)	1.000	1.000	1.000	1.000	1.000	1.000
Frequency (kHz)		38.00		120.00		200.00
Draft correction (m)		0.00		0.00		0.00
Nominal angle (°)		7.10		9.30		7.10

Yuzhmorgeologiya	38 kHz		120 kHz		200 kHz	
	Logging	Processing	Logging	Processing	Logging	Processing
Absorption coef. (dB/m)	0.010000	0.010000	0.026000	0.028000	0.040000	0.041000
Sound speed (m/s)	1485.00	1456.00	1485.00	1456.00	1485.00	1456.00
Transmitted power (W)	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
2-way beam angle (dB)	-15.90	-15.90	-20.40	-20.40	-20.50	-20.50
S_V gain (dB)	22.43	22.36	25.37	25.26	26.12	25.96
Wavelength (m)	0.03868	0.03844	0.01225	0.01223	0.00735	0.00728
Trans. pulse length (ms)	1.000	1.000	1.000	1.000	1.000	1.000
Frequency (kHz)		37.88		119.05		200.00
Draft correction (m)		0.00		0.00		0.00
Nominal angle (°)		12.20		7.10		7.10

Kaiyo Maru	38 kHz		120 kHz		200 kHz	
	Logging	Processing	Logging	Processing	Logging	Processing
Absorption coef. (dB/m)	0.010000	0.010000	0.026000	0.028000	0.040000	0.041000
Sound speed (m/s)	1449.00	1456.00	1449.00	1456.00	1449.00	1456.00
Transmitted power (W)	2000.00	2000.00	1000.00	1000.00	1000.00	1000.00
2-way beam angle (dB)	-20.90	-20.90	-20.60	-20.60	-20.50	-20.50
S_V gain (dB)	27.06	27.06	24.74	24.74	25.76	25.76
Wavelength (m)	0.03868	0.03844	0.01225	0.01223	0.00735	0.00728
Trans. pulse length (ms)		1.000		1.000		1.000
Frequency (kHz)		38.00		119.00		200.00
Draft correction (m)		0.00		0.00		0.00
Nominal angle (°)		7.10		7.10		7.10

Table 11: Calibration parameters for the *Atlantida*, *James Clark Ross*, *Kaiyo Maru* and *Yuzhmorgeologiya*.

Atlantida						
Date	13-Jan-00	05-Feb-00	13-Jan-00	05-Feb-00	13-Jan-00	05-Feb-00
Location	Stromness Bay	Stromness Bay	Stromness Bay	Stromness Bay	Stromness Bay	Stromness Bay
Transducer	ES38B	ES38B	ES120-7	ES120-7	200_28	200_28
Water depth (m)	56	53	54	53	54	53
Sound speed (m/s)	1 457	1 460	1 457	1 460	1 457	1 460
Alpha (dB/km)	10	10	28	28	41	41
Transmit power (watts)	2 000	2 000	1 000	1 000	1 000	1 000
Pulse duration (m/s)	1	1	1	1	1	1
Bandwidth (kHz)	3.8 (10%)	3.8 (10%)	1.2 (1%)	1.2 (1%)	2.0 (1%)	2.0 (1%)
2-way beam angle (dB)	-21.2	-21.2	-20.9	-20.9	-20.3	-20.3
Sphere type	60.0 mm CU	38.1 mm WC	23.0 mm CU	38.1 mm WC	13.7 mm CU	38.1 mm WC
Range to sphere (m)	17.1	14.5	15.0	15.9	14.7	15.5
Calibrated TS gain (dB)	23.76	23.50	23.29	24.66	24.50	23.47
Calibrated S_v gain (dB)	23.43	23.32	23.23	24.49	24.83	23.26
James Clark Ross						
Date	16-Jan-00	12-Feb-00	16-Jan-00	12-Feb-00	16-Jan-00	12-Feb-00
Location	Stromness Bay	Admiralty Bay	Stromness Bay	Admiralty Bay	Stromness Bay	Admiralty Bay
Transducer	ES38B	ES38B	ES120	ES120	200_28	200_28
Water depth (m)	54	264	54	264	54	264
Sound speed (m/s)	1 458	1 455	1 458	1 455	1 458	1 455
Alpha (dB/km)	10	10	27	27	41	41
Transmit power (watts)	2 000	2 000	1 000	1 000	1 000	1 000
Pulse duration (m/s)	1	1	1	1	1	1
Bandwidth (kHz)	3.8 (10%)	3.8 (10%)	1.2 (1%)	1.2 (1%)	2.0 (1%)	2.0 (1%)
2-way beam angle (dB)	-20.8	-20.8	-18.4	-18.4	-20.8	-20.8
Sphere type	38.1 mm WC	38.1 mm WC	38.1 mm WC	38.1 mm WC	38.1 mm WC	38.1 mm WC
Range to sphere (m)	27.7	29.9	28.2	29.73	28.2	28.7
Calibrated TS gain (dB)	25.60	25.60	20.26	20.15	23.07	23.16
Calibrated S_v gain (dB)	25.49	25.53	20.26	20.09	22.78	23.04
Kaiyo Maru						
Date	09-Jan-00	04-Feb-00	09-Jan-00	04-Feb-00	09-Jan-00	04-Feb-00
Location	Stromness Bay	Admiralty Bay	Stromness Bay	Admiralty Bay	Stromness Bay	Admiralty Bay
Transducer	ES38B	ES38B	ES120-7	ES120-7	200_28	200_28
Water depth (m)	80	58	80	58	80	58
Sound speed (m/s)	1 453	1 453	1 453	1 453	1 453	1 453
Alpha (dB/km)	10	10	28	27	41	40.5
Transmit power (watts)	2 000	2 000	1 000	1 000	1 000	1 000
Pulse duration (m/s)	1	1	1	1	1	1
Bandwidth (kHz)	3.8 (10%)	3.8 (10%)	1.2 (1%)	1.2 (1%)	2.0 (1%)	2.0 (1%)
2-way beam angle (dB)	-20.9	-20.9	-20.6	-20.6	-20.5	-20.5
Sphere type	38.1 mm WC	38.1 mm WC	38.1 mm WC	38.1 mm WC	38.1 mm WC	38.1 mm WC
Range to sphere (m)	30.6	30.0	30.0	29.9	30.5	30.1
Calibrated TS gain (dB)	27.32	27.35	24.83	24.55	25.78	25.77
Calibrated S_v gain (dB)	27.06	27.09	24.74	24.30	25.76	25.74
Yuzhmorgeologiya						
Date	12-Jan-00	07-Mar-00	12-Jan-00	07-Mar-00	12-Jan-00	07-Mar-00
Location	Stromness Bay	Admiralty Bay	Stromness Bay	Admiralty Bay	Stromness Bay	Admiralty Bay
Transducer	ES38-12	ES38-12	ES120-7	ES120-7	200_28	200_28
Water depth (m)	88	75	88	75	88	75
Sound speed (m/s)	1 450	1 450	1 450	1 450	1 450	1 450
Alpha (dB/km)	10	10	26	26	40	40
Transmit power (watts)	1 000	1 000	1 000	1 000	1 000	1 000
Pulse duration (m/s)	1	1	1	1	1	1
Bandwidth (kHz)	3.8 (10%)	3.8 (10%)	1.2 (1%)	1.2 (1%)	2.0 (1%)	2.0 (1%)
2-way beam angle (dB)	-15.9	-15.9	-20.4	-20.4	-20.5	-20.5
Sphere type	38.1 mm WC	38.1 mm WC	38.1 mm WC	38.1 mm WC	38.1 mm WC	38.1 mm WC
Range to sphere (m)	30.0	38.0	29.2	37.6	29.0	37.6
Calibrated TS gain (dB)	22.64	22.37	25.56	25.17	26.12	25.80
Calibrated S_v gain (dB)	22.36	22.29	25.37	25.16	22.78	25.80

Table 12: Equivalent two-way beam angle correction for sound speed for the four vessels.

Sound speed during Simrad calibration:	1 473 m/s
Sound speed during survey:	1 449 m/s
Sound speed ratio:	0.9837
Ratio squared:	0.9676
Ratio dB:	-0.1426

Transducer Frequency	Transducer Type	Simrad Specified Beam Angle (dB)	Corrected Beam Angle dB (= specified + dB ratio)
James Clark Ross			
38	ES38B	-20.7	-20.8
120	ES120	-18.3	-18.4
200	200_28	-20.7	-20.8
Kaiyo Maru			
38	ES38B	-20.9	*
120	ES120-7	-20.6	*
200	200_28	-20.5	*
Atlantida			
38	ES38B	-21.2	-21.3
120	ES120-7	-20.9	-21.0
200	200_28	-20.2	-20.3
Yuzhmorgeologiya			
38	ES38-12	-15.9	*
120	ES120-7	-20.4	*
200	200_28	-20.5	*

* Default values supplied by Simrad were used during the survey.

Table 13: *James Clark Ross* CCAMLR-2000 Survey transect times. (See Table 4 for transect abbreviations).

Transect	Begin		End		BAS ID	Comments
	Date	Time	Date	Time		
SS01	18-Jan	1737	18-Jan	2300	T10	
	19-Jan	0527	19-Jan	1359	T11	
	19-Jan	1637	19-Jan	2320	T12	
	20-Jan	0501	20-Jan	1204	T13	
	20-Jan	1505	20-Jan	2345	T14	
	21-Jan	0430	21-Jan	1400	T15	
	21-Jan	1624	21-Jan	1855	T16	
SS04						T17 transit from SS01 to SS04
	22-Jan	1324	22-Jan	1435	T18	
	22-Jan	1702	23-Jan	0015	T19	
	23-Jan	0505	23-Jan	0842	T20	
	23-Jan	0944	24-Jan	1430	T21	
	23-Jan	1611	23-Jan	2345	T22	
	24-Jan	0530	24-Jan	1432	T23	
	24-Jan	1658	24-Jan	2320	T24	
	25-Jan	1546	25-Jan	2321	T25	
SS07						T26 transit from SS04 to SS07
	26-Jan	2231	26-Jan	2320	T27	
	27-Jan	0634	27-Jan	1002	T28	
	27-Jan	1107	27-Jan	1451	T29	
	27-Jan	1609	27-Jan	2340	T30	
	28-Jan	0620	28-Jan	1433	T31	
	28-Jan	1716	29-Jan	0000	T32	
	29-Jan	0600	29-Jan	1356	T33	
	29-Jan	1629	30-Jan	0030	T34	
	30-Jan	0807	30-Jan	1116	T35	
	30-Jan	1214	30-Jan	1505	T36	
	30-Jan	1610	30-Jan	2020	T37	
SS10						T38 transit from SS07 to SS10
	2-Feb	0718	2-Feb	1225	T40	
	2-Feb	1541	3-Feb	0045	T41	
	3-Feb	0620	3-Feb	1524	T42	
AP13						T43 transit from SS10 to AP13
	4-Feb	0606	04-Feb	0748	T44	
	4-Feb	0854	4-Feb	1542	T45	
	4-Feb	1707	4-Feb	2127	T46	
	5-Feb	0635	5-Feb	1418	T48	
AP16						T49 transit from AP13 to AP16
	6-Feb	0900	6-Feb	1613	T50	
	6-Feb	1821	6-Feb	0055	T51	
AP19						T52 transit from AP16 to AP19
	8-Feb	0025	8-Feb	0153	T53	
	8-Feb	0756	8-Feb	1621	T54	
	8-Feb	1900	9-Feb	0205	T55	
	9-Feb	0722	9-Feb	1433	T56	
	9-Feb	1709	9-Feb	2020	T57	
AP16						T58 transit from AP19 back to AP16
	10-Feb	2308	11-Feb	0054	T59	Inner end AP16

Table 14: *Kaiyo Maru* CCAMLR-2000 Survey transect times. (See Table 4 for transect abbreviations).

Transect	Begin		End		Comments
	Date	Time	Date	Time	
SS03	10-Jan	2123	10-Jan	2325	
	11-Jan	0538	11-Jan	1321	
	11-Jan	1547	11-Jan	2345	
	12-Jan	0518	12-Jan	1323	
	12-Jan	1600	13-Jan	0015	
	13-Jan	0449	13-Jan	1323	
	13-Jan	1539	14-Jan	0056	
	14-Jan	0405	14-Jan	0600	
SS06	14-Jan	1830	15-Jan	0056	
	15-Jan	0449	15-Jan	1346	
	15-Jan	1555	16-Jan	0020	
	16-Jan	0527	16-Jan	1347	
	16-Jan	1554	16-Jan	2355	
	17-Jan	0549	17-Jan	1455	
	17-Jan	1710	17-Jan	2141	
SS09	19-Jan	0624	19-Jan	1414	
	19-Jan	1633	20-Jan	0043	
	20-Jan	0603	20-Jan	1415	
	20-Jan	1630	21-Jan	0122	
	21-Jan	0526	21-Jan	1428	
	21-Jan	1646	21-Jan	2024	
AP12	22-Jan	0018	22-Jan	0158	
	22-Jan	0524	22-Jan	1438	
	22-Jan	1655	23-Jan	0015	
	23-Jan	0553	23-Jan	1802	
AP15	24-Jan	1010	24-Jan	1511	
	24-Jan	1815	25-Jan	0215	
	25-Jan	0631	25-Jan	1340	
AP18	26-Jan	0910	26-Jan	1530	
	26-Jan	1751	27-Jan	0238	
	27-Jan	0643	27-Jan	1538	
	27-Jan	1755	28-Jan	0219	

Table 15: *Kaiyo Maru* CCAMLR-2000 Survey mesoscale transects. (See Table 4 for transect abbreviations).

Transect	Begin		End		Comments
	Date	Time	Date	Time	
SSI01	29-Jan	0703	29-Jan	1429	
	29-Jan	1646	29-Jan	1703	
SSI02	29-Jan	1910	29-Jan	2350	
SSI03	30-Jan	0701	30-Jan	1210	
SSI04	30-Jan	1552	30-Jan	1614	
	30-Jan	1805	30-Jan	2131	
SSI05	31-Jan	0701	31-Jan	1118	
SSI06	31-Jan	1614	31-Jan	1626	
	31-Jan	1803	31-Jan	2212	
SSI07	1-Feb	0723	1-Feb	1203	
SSI08	1-Feb	1956	2-Feb	0101	

Table 16: *Atlantida* CCAMLR-2000 Survey transect times. (See Table 4 for transect abbreviations).

Transect	Begin		End		Comments
	Date	Time	Date	Time	
SSa	22-Jan	0500	22-Jan	1322	
	22-Jan	1518	22-Jan	2235	
	23-Jan	0442	23-Jan	1330	
	23-Jan	1628	23-Jan	2301	
	24-Jan	0405	24-Jan	1239	
SSb	25-Jan	0413	25-Jan	1154	
	25-Jan	1458	25-Jan	2207	
	26-Jan	0455	26-Jan	1332	
	26-Jan	1842	26-Jan	2253	
	27-Jan	0513	27-Jan	1206	
	27-Jan	1454	27-Jan	2228	
	28-Jan	0528	28-Jan	1316	
SSc	29-Jan	0527	29-Jan	1314	
	29-Jan	1539	29-Jan	2211	
	30-Jan	0514	30-Jan	1238	
	30-Jan	1359	30-Jan	2246	
	31-Jan	0443	31-Jan	1235	
	31-Jan	1508	31-Jan	2253	
	1-Feb	0432	1-Feb	0822	

Table 17: *Atlantida* CCAMLR-2000 Survey mesoscale transects. (See Table 4 for transect abbreviations).

Transect	Begin		End		Comments
	Date	Time	Date	Time	
Sand01	17-Jan	1000	17-Jan	1324	
	17-Jan	1502	17-Jan	1752	
Sand02	17-Jan	1908	17-Jan	2146	
	18-Jan	0412	18-Jan	0544	
Sand03	18-Jan	0551	18-Jan	1104	
Sand04	18-Jan	1149	18-Jan	1255	
	18-Jan	1630	18-Jan	1742	
Sand05	18-Jan	1805	18-Jan	2323	
Sand06	19-Jan	0641	19-Jan	1119	
Sand07	19-Jan	1220	19-Jan	1321	
	19-Jan	1503	19-Jan	1731	
Sand08	19-Jan	1906	20-Jan	0017	
Sand09	20-Jan	0513	20-Jan	1118	
Sand10	20-Jan	1147	20-Jan	1302	
	20-Jan	1559	20-Jan	1833	

Table 18: *Yuzhmorgeologiya* CCAMLR-2000 Survey transects times. (See Table 4 for transect abbreviations).

Transect	Begin		End		Comments
	Date	Time	Date	Time	
SS02	16-Jan	0535	16-Jan	0809	
	16-Jan	1002	16-Jan	1417	
	16-Jan	1510	16-Jan	2323	
	17-Jan	0525	17-Jan	1243	
	17-Jan	1555	17-Jan	2046	
	18-Jan	0502	18-Jan	1420	
	18-Jan	1635	19-Jan	0019	
	19-Jan	0502	19-Jan	1420	
	19-Jan	1754	19-Jan	2042	
					Transit to SS05
SS05	20-Jan	1148	20-Jan	1442	
	20-Jan	1632	21-Jan	0035	
	21-Jan	0522	21-Jan	1148	
	21-Jan	1358	22-Jan	0003	
	22-Jan	0528	22-Jan	1445	
	22-Jan	1907	22-Jan	2352	
	23-Jan	0537	23-Jan	1438	
	23-Jan	1546	23-Jan	2335	
					Transit to SS08
SS08	25-Jan	1721	26-Jan	0013	
	26-Jan	0609	26-Jan	1324	
	26-Jan	1549	26-Jan	2139	
	27-Jan	0551	27-Jan	1520	
	28-Jan	0520	28-Jan	1503	
					Transit to AP11
AP11	31-Jan	0056	1-Feb	0052	
					Transit to AP14
AP14	1-Feb	2008	2-Feb	0134	
	2-Feb	0638	2-Feb	1610	
					Transit to AP17
AP17	3-Feb	0837	4-Feb	0208	
	4-Feb	0730	4-Feb	1642	
	4-Feb	1850	4-Feb	2019	

Table 19: *Yuzhmorgeologiya* CCAMLR-2000 Survey mesoscale transects. (See Table 4 for transect abbreviations).

Transect	Begin		End		Comments
	Date	Time	Date	Time	
SG04	13-Jan	1052	13-Jan	1437	
	13-Jan	1910	13-Jan	1936	
					Transit to SG03
SG03	13-Jan	2238	13-Jan	2339	
	14-Jan	0651	14-Jan	1105	
					Transit to SG02
SG02	14-Jan	1726	14-Jan	2255	
					Transit to SG01
SG01	15-Jan	0542	15-Jan	1044	
					Transit to SOI01
SOI01	29-Jan	0812	29-Jan	1315	
					Transit to SOI02
SOI02	29-Jan	1841	29-Jan	2255	
					Transit to SOI03
SOI03	30-Jan	0549	30-Jan	0957	
					Transit to SOI04
SOI04	30-Jan	1504	30-Jan	1830	

Table 20: Steps implemented in Echoview 2.00. Raw variables: Q1 – 38 kHz raw data; Q2 – 120 kHz raw data; Q3 – 200 kHz raw data.

Steps	Virtual Variables				
	Name	Operator	Operand1	Operand2	Other Settings Required
Define inclusions	Surf-bott	Line bitmap	Q1		Surface exclusion to integration stop line
	Good data	Region bitmap	Q1		Bad data regions, INVERT output
	Include	AND	Surf-bott	Good data	
Mask echograms	38-E	Mask	Q1	Include	DO check zero is no data
	120-E	Mask	Q2	Include	DO check zero is no data
	200-E	Mask	Q3	Include	DO check zero is no data
Resample masked echograms	38-S	Resample by time	38-E		100 seconds, 0–500 m, 100 samples
	120-S	Resample by time	120-E		100 seconds, 0–500 m, 100 samples
	200-S	Resample by time	200-E		100 seconds, 0–500 m, 100 samples
Generate noise	Noise 38	Data generator	38-S		Use noise(s_v)1 m from table; set α = 0.010
	Noise 120	Data generator	120-S		Use noise(s_v)1 m from table; set α = 0.028
	Noise 200	Data generator	200-S		Use noise(s_v)1 m from table; set α = 0.041
Subtract noise from resampled echograms	38-S-C	Linear minus	38-S	Noise 38	
	120-S-C	Linear minus	120-S	Noise 120	
	200-S-C	Linear minus	200-S	Noise 200	
Subtract (120-38)	Dif-S 120-38	Minus	120-S-C	38-S-C	Set display min s_v to 0
Define dB range	Range Dif-S	Range	Dif-S 120-38		Range 2–16
Mask resampled noise-free echograms	Mask 38-S-C	Mask	38-S-C	Range Dif-S	Do NOT check zero is no data, add grid
	Mask 120-S-C	Mask	120-S-C	Range Dif-S	Do NOT check zero is no data, add grid
	Mask 200-S-C	Mask	200-S-C	Range Dif-S	Do NOT check zero is no data, add grid
					Process tab: exclude above = surface exclusion; exclude below = integration stop.

Table 21: Conversion factor, integrated volume backscattering (S_A, m^2/n miles^2) to areal krill biomass density (g/m^2).

	Cluster 1	Cluster 2	Cluster 3	Clusters 2+3	Clusters 1+2+3
120 kHZ					
FIBEX 1	0.1481	0.1523	0.1536	0.1526	0.1508
FIBEX 2	0.1656	0.1583	0.1557	0.1576	0.1609
CCAMLR-2000	0.1636	0.1517	0.1477	0.1506	0.1560
Morris et al. (1988)	0.1931	0.1703	0.1630	0.1684	0.1785
Siegel (1992)	0.1556	0.1449	0.1414	0.1440	0.1487
38 kHz					
FIBEX 1	0.4672	0.4805	0.4847	0.4815	0.4757
FIBEX 2	0.5224	0.4993	0.4913	0.4971	0.5075
CCAMLR-2000	0.5163	0.4786	0.4661	0.4753	0.4921
Morris et al. (1988)	0.6092	0.5372	0.5142	0.5311	0.5630
Siegel (1992)	0.4909	0.4573	0.4461	0.4543	0.4693
200 kHz					
FIBEX 1	0.0888	0.0914	0.0921	0.0915	0.0904
FIBEX 2	0.0993	0.0949	0.0934	0.0945	0.0964
CCAMLR-2000	0.0982	0.0910	0.0886	0.0904	0.0936
Morris et al. (1988)	0.1158	0.1021	0.0977	0.1010	0.1070
Siegel (1992)	0.0933	0.0869	0.0848	0.0864	0.0892

Table 22: Expected change in latitude (Δlat) per nautical mile of transect. (See Table 4 for transect abbreviations).

Transect	Δlat	Transect	Δlat	Transect	Δlat
SS01	0.01649	SSI01	0.01496	Sand01	0.01635
SS02	0.01657	SSI02	0.01507	Sand02	0.01632
SS03	0.01662	SSI03	0.01519	Sand03	0.01630
SS04	0.01665	SSI04	0.01532	Sand04	0.01629
SS05	0.01666	SSI05	0.01539	Sand05	0.01628
SS06	0.01667	SSI06	0.01554	Sand06	0.01639
SS07	0.01665	SSI07	0.01559	Sand07	0.01637
SS08	0.01662	SSI08	0.01574	Sand08	0.01637
SS09	0.01656	S0I1	0.01665	Sand09	0.01635
SS10	0.01650	S0I2	0.01664	Sand10	0.01632
SSa	0.01625	S0I3	0.01662		
SSb	0.01635	S0I4	0.01660		
SSc	0.01643	SG01	0.01662		
AP11	0.01451	SG02	0.01663		
AP12	0.01463	SG03	0.01665		
AP13	0.01487	SG04	0.01666		
AP14	0.01521				
AP15	0.01546				
AP16	0.01561				
AP17	0.01590				
AP18	0.01599				
AP19	0.01613				

Table 23: Planned transect length (km) sampled within each subarea.

Subarea	Large-scale	Mesoscale	Total	% in each Subarea
48.1	3 818	800	4 618	25.6
48.2	4 413	400	4 813	26.6
48.3	4 219	400	4 619	25.6
48.4	2 993	1 000	3 993	22.1

Table 24a: Mean krill density and associated variance by transect and stratum estimated from acoustic data collected at 38 kHz. (See Table 4 for transect abbreviations and Attachment D for description of calculations).

Transect						Stratum Krill Density		
Name	Length (n miles)	Weighting Factor	Krill Density Measured (g/m^2)	Krill Density Weighted (g/m^2)	Variance Component	Mean (g/m^2)	Variance	CV (%)
AP11	95.99	0.67	5.02	3.36	13.10	10.42	6.46	24.38
AP12	194.66	1.36	18.18	24.70	111.15			
AP13	133.00	0.93	10.30	9.56	0.01			
AP14	76.59	0.53	13.77	7.36	3.20			
AP15	108.14	0.75	25.29	19.09	125.96			
AP16	90.29	0.63	13.41	8.45	3.55			
AP17	156.60	1.09	8.77	9.59	3.26			
AP18	228.75	1.60	5.33	8.51	66.08			
AP19	205.40	1.43	2.22	3.18	138.48			
SS01	431.22	1.23	9.29	11.46	42.77	14.60	2.68	11.21
SS02	416.33	1.19	15.16	18.06	0.46			
SS03	364.24	1.04	14.33	14.92	0.08			
SS04	312.13	0.89	18.44	16.46	11.78			
SS05	397.78	1.14	14.07	16.00	0.36			
SS06	402.61	1.15	11.25	12.95	14.87			
SS07	379.43	1.09	25.92	28.13	150.99			
SS08	271.53	0.78	15.85	12.31	0.94			
SS09	346.36	0.99	11.19	11.09	11.37			
SS10	175.13	0.50	9.18	4.60	7.36			
SSa	327.02	1.07	5.66	6.06	7.95	8.29	13.38	44.13
SSb	199.88	0.66	1.51	0.99	19.70			
SSc	388.56	1.27	13.99	17.81	52.67			
SSI01	37.87	1.09	58.10	63.39	15.53	54.49	105.20	18.82
SSI02	35.11	1.01	28.57	28.90	687.32			
SSI03	38.34	1.10	78.25	86.44	688.95			
SSI04	28.67	0.83	45.71	37.75	52.63			
SSI05	31.56	0.91	30.65	27.86	469.78			
SSI06	32.88	0.95	42.78	40.52	122.99			
SSI07	35.14	1.01	111.84	113.21	3 369.89			
SSI08	38.13	1.10	34.46	37.85	484.16			
SOI01	38.71	1.22	6.52	7.98	7 222.60	75.93	1678.90	53.96
SOI02	32.65	1.03	100.27	103.54	631.75			
SOI03	29.61	0.94	185.27	173.50	10 483.16			
SOI04	25.51	0.81	23.20	18.71	1 809.31			
SG01	38.47	1.03	17.68	18.23	53.02	10.62	9.78	29.45
SG02	39.48	1.06	3.38	3.57	58.60			
SG03	39.07	1.05	12.40	12.98	3.48			
SG04	32.26	0.86	8.89	7.69	2.22			
Sand01	42.27	1.13	23.32	26.32	125.01	13.41	4.49	15.79
Sand02	38.89	1.04	16.77	17.41	12.15			
Sand03	38.35	1.02	15.56	15.94	4.85			
Sand04	36.60	0.98	11.10	10.84	5.13			
Sand05	39.33	1.05	7.13	7.49	43.55			
Sand06	36.28	0.97	21.71	21.03	64.64			
Sand07	27.21	0.73	15.12	10.99	1.54			
Sand08	37.09	0.99	5.06	5.01	68.41			
Sand09	39.57	1.06	5.02	5.30	78.64			
Sand10	38.96	1.04	13.27	13.80	0.02			

Table 24b: Mean krill density and standing stock, and associated variances, by stratum and for the entire survey, estimated from acoustic data collected at 38 kHz. (See Table 4 for transect abbreviations and Attachment D for description of calculations).

Stratum	Nominal Area (km^2)	Mean Density (g/m^2)	Area*Density (million tonnes)	Variance Component
AP (11–19)	473 318	10.42	4 933 506.55	1 446 231 977 393.93
SS (01–10)	1 109 789	14.60	16 199 493.48	3 297 868 733 235.00
SS (a–c)	321 800	8.29	2 667 686.01	1 386 065 333 392.42
SSI (01–08)	48 654	54.49	2 651 158.06	249 033 424 971.57
SOI (01–04)	24 409	75.93	1 853 439.54	1 000 288 115 684.75
SG (01–04)	25 000	10.62	265 399.27	6 110 386 467.47
Sand (01–10)	62 274	13.41	835 277.60	17 405 436 721.73
Total	206 5244		29 405 960.52	7 403 003 407 866.88
Survey				
Mean density	14.24	g/m^2		
Variance	1.74	$(g/m^2)^2$		
CV	9.25	%		
Krill standing stock	29.41	million tonnes		
Variance	7 403 003.41	million $tonnes^2$		
CV	9.25	%		

Table 25a: Mean krill density and associated variance by transect and stratum estimated from acoustic data collected at 120 kHz. (See Table 4 for transect abbreviations and Attachment D for description of calculations).

Transect						Stratum Krill Density		
Name	Length (n miles)	Weighting Factor	Krill Density Measured (g/m²)	Krill Density Weighted (g/m²)	Variance Component	Mean (g/m²)	Variance	CV (%)
AP11	95.99	0.67	12.83	8.59	1.13	11.24	4.70	19.29
AP12	194.66	1.36	15.58	21.17	34.79			
AP13	133.00	0.93	11.79	10.94	0.26			
AP14	76.59	0.53	18.06	9.65	13.29			
AP15	108.14	0.75	22.88	17.27	77.18			
AP16	90.29	0.63	13.22	8.33	1.56			
AP17	156.60	1.09	10.57	11.55	0.54			
AP18	228.75	1.60	5.30	8.46	89.92			
AP19	205.40	1.43	3.61	5.18	119.59			
SS01	431.22	1.23	20.38	25.14	26.28	24.54	14.07	15.28
SS02	416.33	1.19	47.53	56.60	749.40			
SS03	364.24	1.04	26.11	27.19	2.66			
SS04	312.13	0.89	30.94	27.62	32.67			
SS05	397.78	1.14	25.49	29.00	1.17			
SS06	402.48	1.15	13.93	16.03	149.20			
SS07	379.43	1.09	30.16	32.73	37.17			
SS08	271.53	0.78	21.40	16.62	5.96			
SS09	346.36	0.99	10.43	10.33	195.34			
SS10	175.13	0.50	8.29	4.15	66.27			
SSa	326.60	1.07	8.18	8.75	11.29	11.32	23.10	42.46
SSb	199.88	0.65	1.97	1.29	37.44			
SSc	389.24	1.28	18.75	23.91	89.85			
SSI01	37.87	1.09	17.73	19.35	476.09	37.73	97.94	26.23
SSI02	35.11	1.01	27.65	27.96	103.96			
SSI03	38.34	1.10	61.30	67.71	677.62			
SSI04	28.67	0.83	14.48	11.96	368.57			
SSI05	31.56	0.91	25.83	23.48	117.00			
SSI06	32.88	0.95	29.89	28.32	55.08			
SSI07	35.14	1.01	95.76	96.94	3 451.40			
SSI08	38.13	1.10	23.78	26.12	234.93			
SOI01	38.71	1.22	12.20	14.93	28 615.52	150.37	6966.86	55.51
SOI02	32.65	1.03	221.61	228.84	5 412.21			
SOI03	29.61	0.94	361.59	338.62	39 127.21			
SOI04	25.51	0.81	23.65	19.08	10 447.39			
SG01	38.47	1.03	70.75	72.94	1 051.46	39.30	146.24	30.77
SG02	39.48	1.06	17.34	18.34	539.47			
SG03	39.07	1.05	42.35	44.34	10.24			
SG04	32.26	0.86	24.95	21.57	153.74			
Sand01	42.27	1.13	27.69	31.25	4.77	25.76	46.15	26.37
Sand02	38.89	1.04	20.88	21.69	25.60			
Sand03	38.35	1.02	20.89	21.39	24.83			
Sand04	36.60	0.98	22.11	21.60	12.72			
Sand05	39.33	1.05	18.09	19.00	64.81			
Sand06	36.28	0.97	85.63	82.94	3 363.21			
Sand07	27.21	0.73	28.11	20.42	2.93			
Sand08	37.09	0.99	10.47	10.37	229.21			
Sand09	39.57	1.06	6.86	7.24	398.80			
Sand10	38.96	1.04	20.83	21.67	26.23			

Table 25b: Mean krill density and standing stock, and associated variances, by stratum and for the entire survey, estimated from acoustic data collected at 120 kHz. (See Table 4 for transect abbreviations and Attachment D for description of calculations).

Stratum	Nominal Area (km^2)	Mean Density (g/m^2)	Area*Density (million tonnes)	Variance Component
AP (11–19)	473 318	11.24	5 319 647.98	1 052 496 388 913.78
SS (01–10)	1 109 789	24.54	27 234 964.55	17 326 537 058 061.60
SS (a–c)	321 800	11.32	3 642 035.01	2 391 655 734 991.07
SSI (01–08)	48 654	37.73	1 835 720.49	231 845 632 004.71
SOI (01–04)	24 409	150.37	3 670 294.56	4 150 849 848 119.59
SG (01–04)	25 000	39.30	982 423.23	91 401 915 350.65
Sand (01–10)	62 274	25.76	1 603 985.17	178 954 989 453.98
Total	2 065 244		44 289 070.99	25 423 741 566 895.40

Survey		
Mean density	21.44	g/m^2
Variance	5.96	$(g/m^2)^2$
CV	11.38	%
Krill standing stock	44.29	million tonnes
Variance	25 423 741.57	million $tonnes^2$
CV	11.38	%

Table 26a: Mean krill density and associated variance by transect and stratum estimated from acoustic data collected at 200 kHz. (See Table 4 for transect abbreviations and Attachment D for description of calculations).

Transect						Stratum Krill Density		
Name	Length (n miles)	Weighting Factor	Krill Density Measured (g/m²)	Krill Density Weighted (g/m²)	Variance Component	Mean (g/m²)	Variance	CV (%)
AP11	95.99	0.67	19.81	13.27	67.62	7.54	3.03	23.09
AP12	194.66	1.36	10.18	13.83	12.88			
AP13	133.00	0.93	7.15	6.63	0.13			
AP14	76.59	0.53	12.56	6.71	7.20			
AP15	108.14	0.75	12.01	9.07	11.42			
AP16	90.29	0.63	7.87	4.96	0.04			
AP17	156.60	1.09	4.83	5.28	8.77			
AP18	228.75	1.60	3.38	5.40	43.97			
AP19	205.40	1.43	1.87	2.68	66.03			
SS01	431.22	1.23	26.39	32.54	46.99	20.83	22.83	22.94
SS02	416.33	1.19	52.90	62.98	1 457.89			
SS03	364.24	1.04	15.56	16.21	30.11			
SS04	312.13	0.89	26.90	24.02	29.43			
SS05	397.78	1.14	18.49	21.04	7.04			
SS06	402.61	1.15	8.05	9.27	216.26			
SS07	379.43	1.09	18.65	20.23	5.59			
SS08	271.53	0.78	14.85	11.53	21.57			
SS09	346.36	0.99	6.68	6.62	196.38			
SS10	175.13	0.50	7.66	3.84	43.46			
SSa	327.04	1.07	23.00	24.65	112.13	32.88	182.73	41.11
SSb	199.88	0.65	8.08	5.29	264.00			
SSc	388.56	1.27	53.96	68.71	720.24			
SSI01	37.87	1.09	24.11	26.31	0.10	23.82	16.84	17.23
SSI02	35.11	1.01	13.91	14.07	100.53			
SSI03	38.34	1.10	32.50	35.90	91.92			
SSI04	28.67	0.83	26.64	22.00	5.42			
SSI05	31.56	0.91	14.51	13.19	71.76			
SSI06	32.88	0.95	18.76	17.77	23.04			
SSI07	35.14	1.01	46.24	46.81	515.18			
SSI08	38.13	1.10	13.24	14.54	135.24			
SOI01	38.71	1.22	10.23	12.52	11 072.17	96.17	2612.93	53.15
SOI02	32.65	1.03	154.86	159.91	3 672.22			
SOI03	29.61	0.94	214.35	200.73	12 248.51			
SOI04	25.51	0.81	14.29	11.53	4 362.27			
SG01	38.47	1.03	94.32	97.25	2 694.41	43.98	307.82	39.90
SG02	39.48	1.06	22.44	23.74	518.79			
SG03	39.07	1.05	35.13	36.78	85.76			
SG04	32.26	0.86	20.99	18.14	394.82			
Sand01	42.27	1.15	51.73	59.49	25.54	47.34	105.62	21.71
Sand02	38.89	1.06	39.51	41.81	68.58			
Sand03	38.35	1.04	52.34	54.61	27.22			
Sand04	36.60	1.00	2.17	2.16	2 022.03			
Sand05	32.33	0.88	60.97	53.62	143.73			
Sand06	36.28	0.99	65.19	64.35	310.63			
Sand07	27.21	0.74	136.64	101.15	4 370.60			
Sand08	37.09	1.01	61.26	61.82	197.45			
Sand09	39.57	1.08	23.18	24.96	676.45			
Sand10	38.96	1.06	8.85	9.38	1 663.85			

Table 26b: Mean krill density and standing stock, and associated variances, by stratum and for the entire survey, estimated from acoustic data collected at 200 kHz. (See Table 4 for transect abbreviations and Attachment D for description of calculations).

Stratum	Nominal Area (km^2)	Mean Density (g/m^2)	Area*Density (million tonnes)	Variance Component
AP (11–19)	473 318	7.54	3 567 466.33	678 506 608 166.80
SS (01–10)	1 109 789	20.83	23 113 322.60	28 118 640 024 444.60
SS (a–c)	321 800	32.88	10 581 899.97	18 922 484 846 099.70
SSI (01–08)	48 654	23.82	1 159 090.11	39 869 126 927.20
SOI (01–04)	24 409	96.17	2 347 454.90	1 556 782 525 132.16
SG (01–04)	25 000	43.98	1 099 399.53	192 384 609 178.69
Sand (01–10)	62 274	47.34	2 947 763.77	409 612 070 977.53
Total	2 065 244		44 816 397.21	49 918 279 810 926.70
Survey				
Mean density	21.70	g/m^2		
Variance	11.70	$(g/m^2)^2$		
CV	15.76	%		
Krill standing stock	44.82	million tonnes		
Variance	49 918 279.81	million tonnes^2		
CV	15.76	%		

Table 27: Results of a single-factor ANOVA testing for differences in krill densities (g/m^2 at 120 kHz) measured by the *James Clark Ross*, *Kaiyo Maru* and *Yuzhmorgeologiya* running interleaved transects in the Scotia Sea (SS) and Antarctic Peninsula (AP) regions. Minor changes to transect means resulting from error checking (paragraph 4.3) are not included. The inclusion of these changes is not expected to alter the conclusions drawn from this table.

Krill density (g/m^2) Ship/transect means	SS01,02,03	SS04,05,06	SS07,08,09	AP13,12,11	AP16,15,14	AP19,18,17
James Clark Ross	20.38	30.94	30.16	11.74	13.22	3.61
Kaiyo Maru	26.11	13.93	10.43	15.58	22.88	5.30
Yuhzmorgeologiya	47.53	25.49	21.40	12.83	18.06	10.57
Summary						
Groups	Count	Sum	Average	Variance		
James Clark Ross	6	110.05	18.34	117.90		
Kaiyo Maru	6	94.22	15.70	59.77		
Yuhzmorgeologiya	6	135.87	22.65	178.46		
ANOVA						
Source of variation	SS	df	MS	F	P-value	F crit
Between groups	147.34	2	73.67	0.62	0.55	3.68
Within groups	1 780.66	15	118.71			
Total	1 927.99	17				

Table 28: Results of a single-factor ANOVA testing for differences in krill densities (g/m^2 at 120 kHz) measured by all four research vessels in the Scotia Sea (SS) and Antarctic Peninsula (AP) regions. Minor changes to transect means resulting from error checking (paragraph 4.3) are not included. The inclusion of these changes is not expected to alter the conclusions drawn from this table.

Krill density (g/m^2)							
Ship/transect means	SS01,02,03	SS04,05,06	SS07,08,09	AP13,12,11	AP16,15,14	AP19,18,17	SS10
James Clark Ross	20.38	30.94	30.16	11.74	13.22	3.61	7.39
Kaiyo Maru	26.11	13.93	10.43	15.58	22.88	5.30	
Yuhzmorgeologiya	47.53	25.49	21.40	12.83	18.06	10.57	
Atlantida	8.18	1.97	18.75				

Summary				
Groups	Count	Sum	Average	Variance
James Clark Ross	7	117.45	16.78	115.38
Kaiyo Maru	6	94.22	15.70	59.77
Yuhzmorgeologiya	6	135.87	22.65	178.46
Atlantida	3	28.90	9.63	71.96

ANOVA						
Source of variation	SS	df	MS	F	P-value	F crit
Between groups	364.17	3	121.39	1.08	0.38	3.16
Within groups	2 027.34	18	112.63			
Total	2 391.51	21				

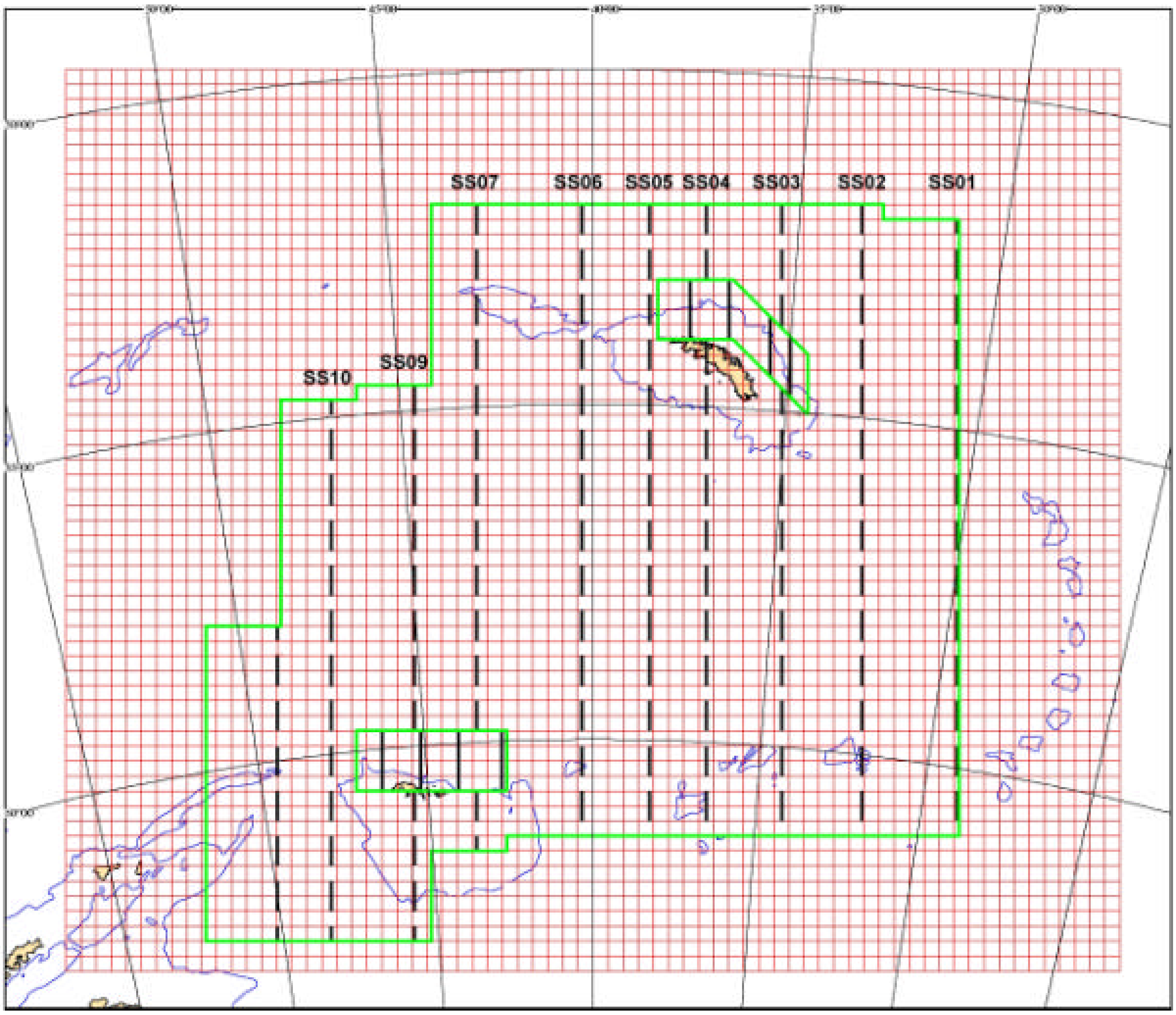

Figure 1a: CCAMLR-2000 Survey strata in the Scotia Sea. The large-scale stratum extends across the region, and two mesoscale survey boxes were located adjacent to South Georgia and the South Orkney Islands. Large-scale transects (SS01-SS10, dashed lines) and mesoscale transects (SG01-SG04 and SOI01-SOI04, solid lines) are shown. The grid squares are 25 x 25 km.

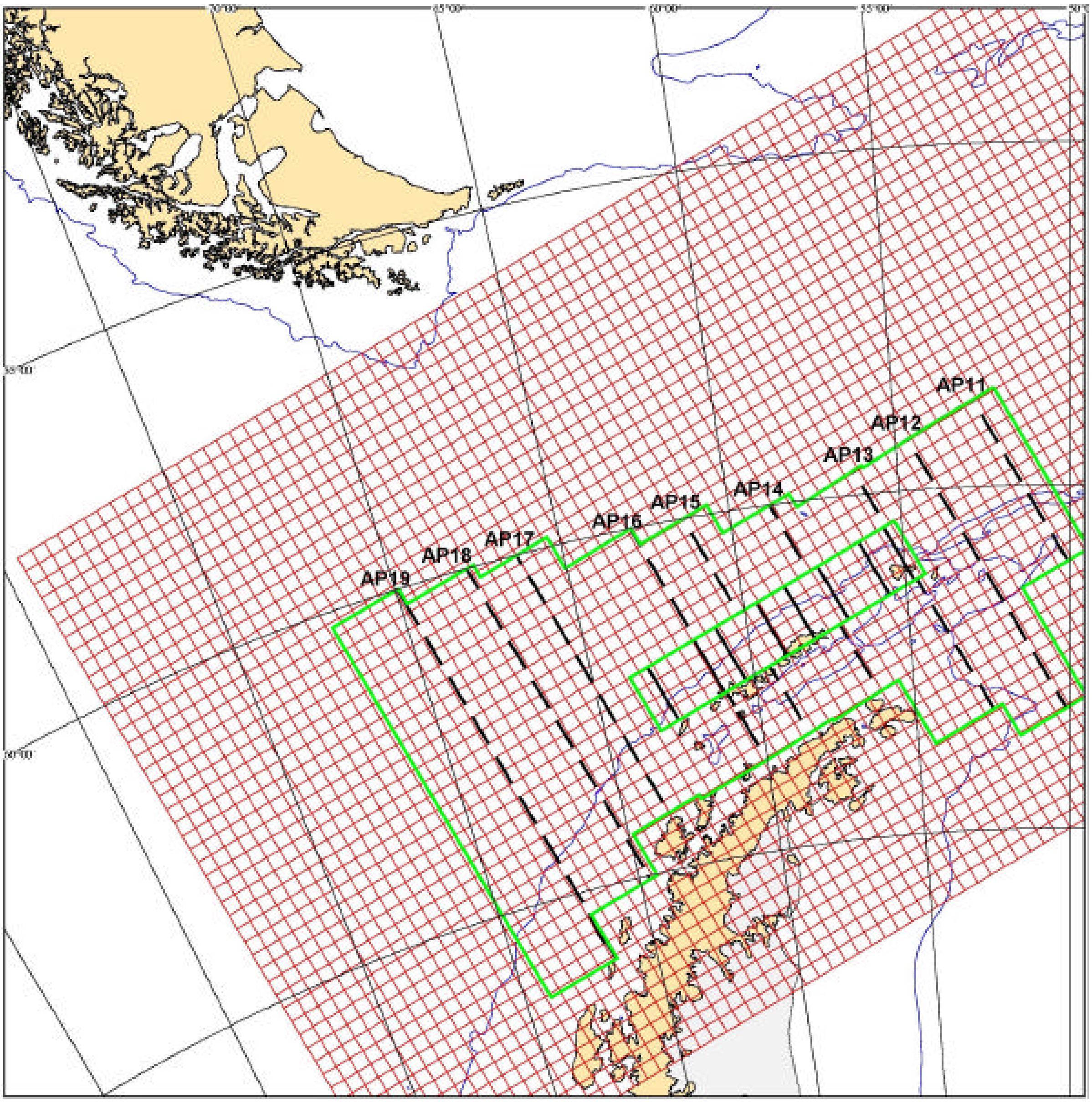

Figure 1b: CCAMLR-2000 Survey strata in the Antarctic Peninsula region. The large-scale stratum extends across the region, and the mesoscale survey box was located adjacent to the South Shetland Islands. Large-scale transects (AP11-AP19, dashed lines) and mesoscale transects (SSI01-08, solid lines) are shown. The grid squares are 25 x 25 km.

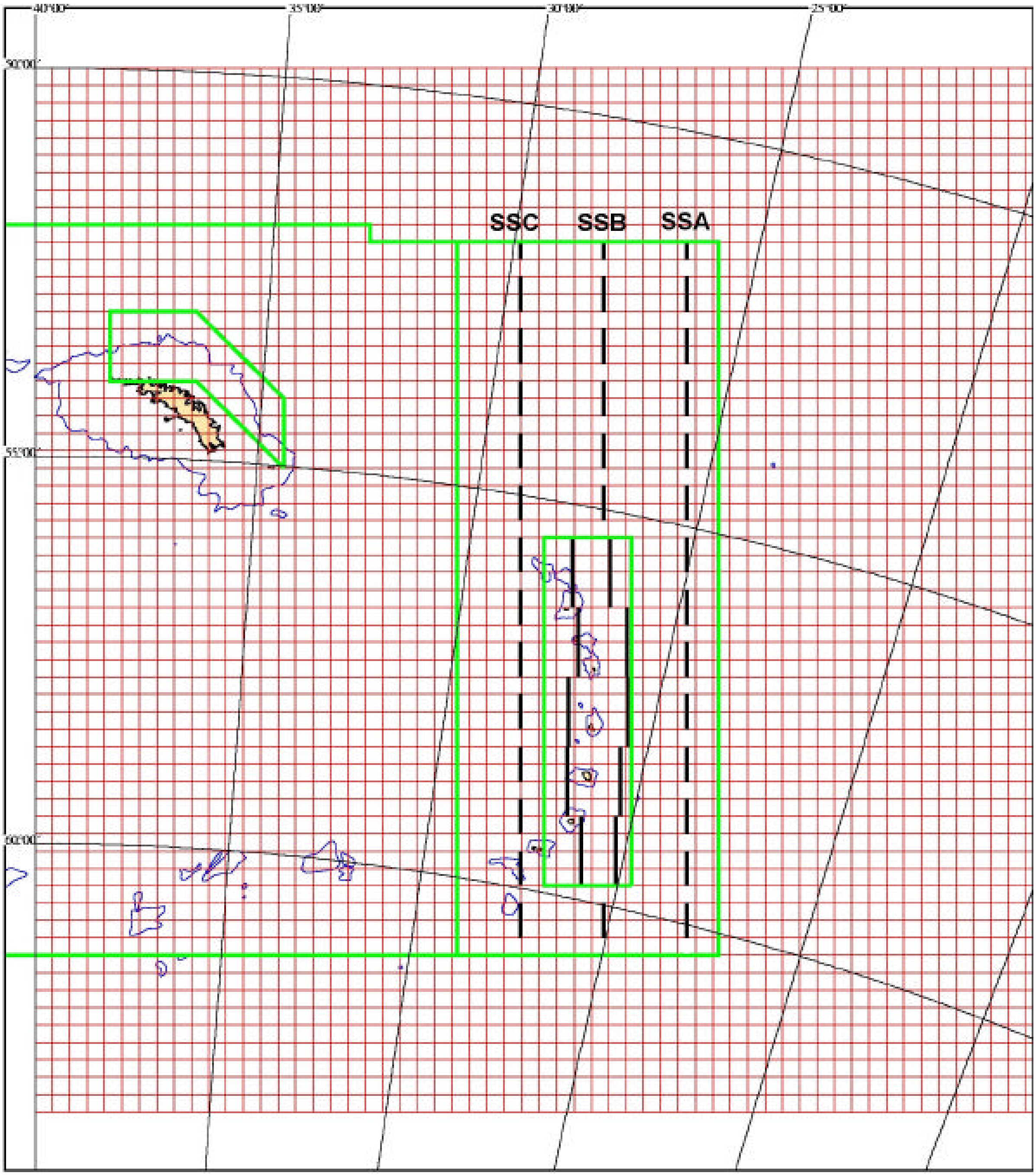

Figure 1c: CCAMLR-2000 Survey strata in the East Scotia Sea. The large-scale stratum extends across the region, and the mesoscale survey box was located adjacent to the South Sandwich Islands. Large-scale transects (SSA-SSC, dashed lines) and mesoscale transects (Sand01-10, solid lines) are shown. The grid squares are 25 x 25 km.

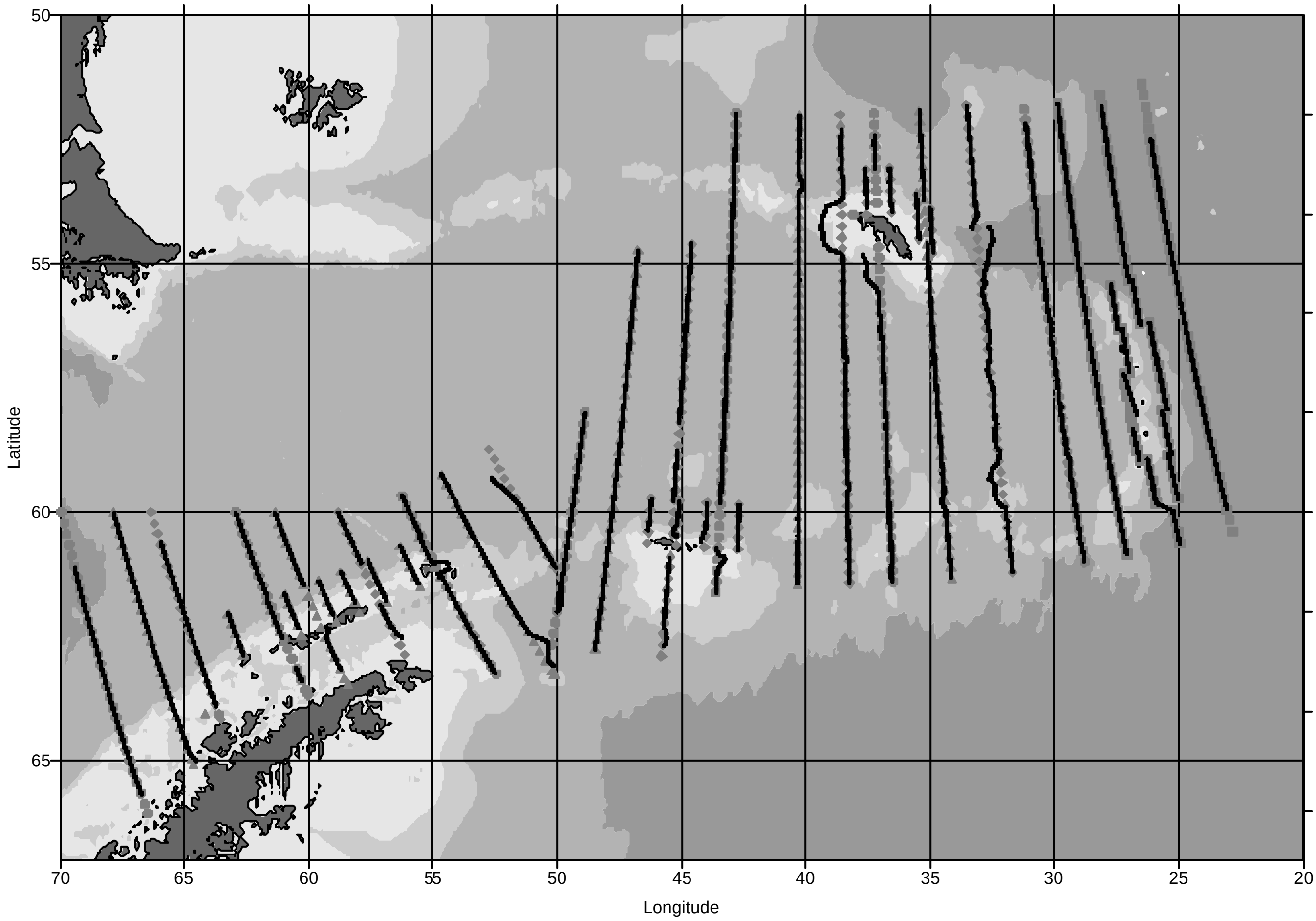

Figure 2: Planned way points for the *Atlantida* (¦), *Kaiyo Maru* (?), *James Clark Ross* (?) and *Yuzhmorgeologiya* (?) and actual transects (solid lines) conducted during the CCAMLR-2000 Survey.

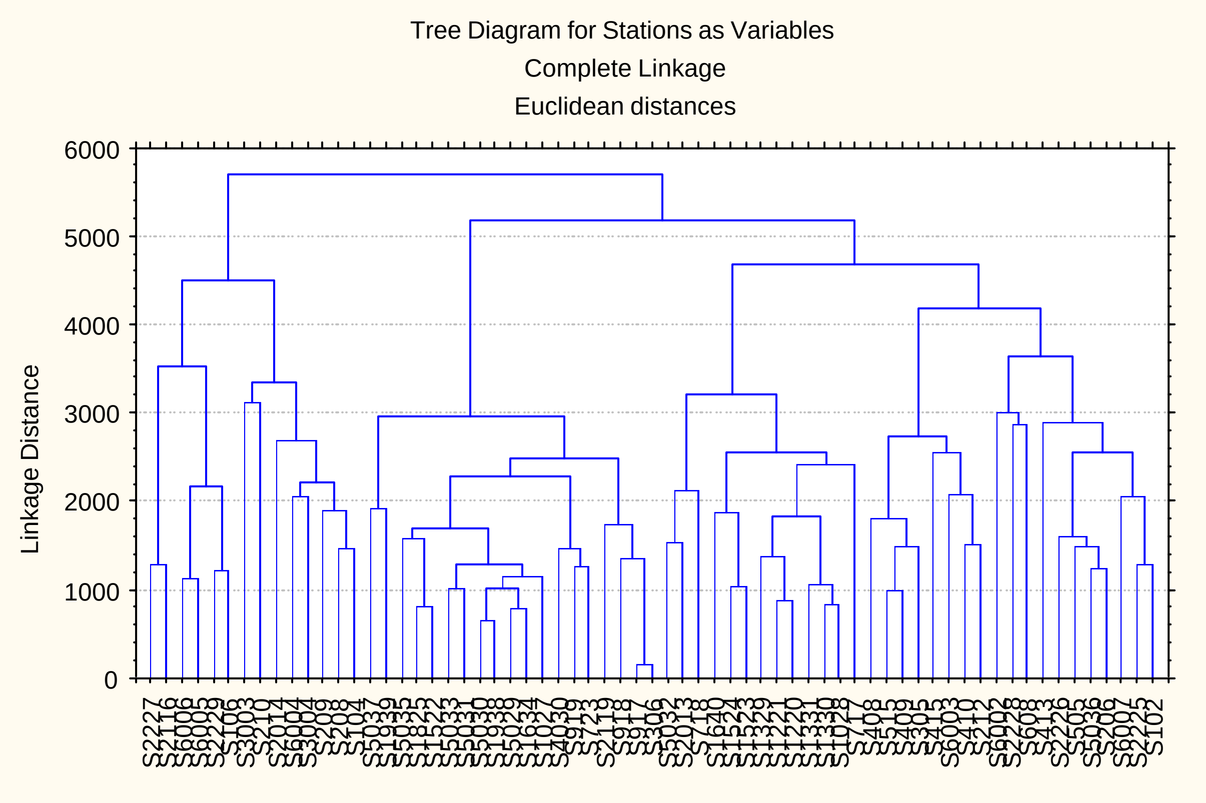

Figure 3: Dendrogram showing the clustering of length-frequency distributions of krill, from RMT8 samples, using the Complete Linkage Method.

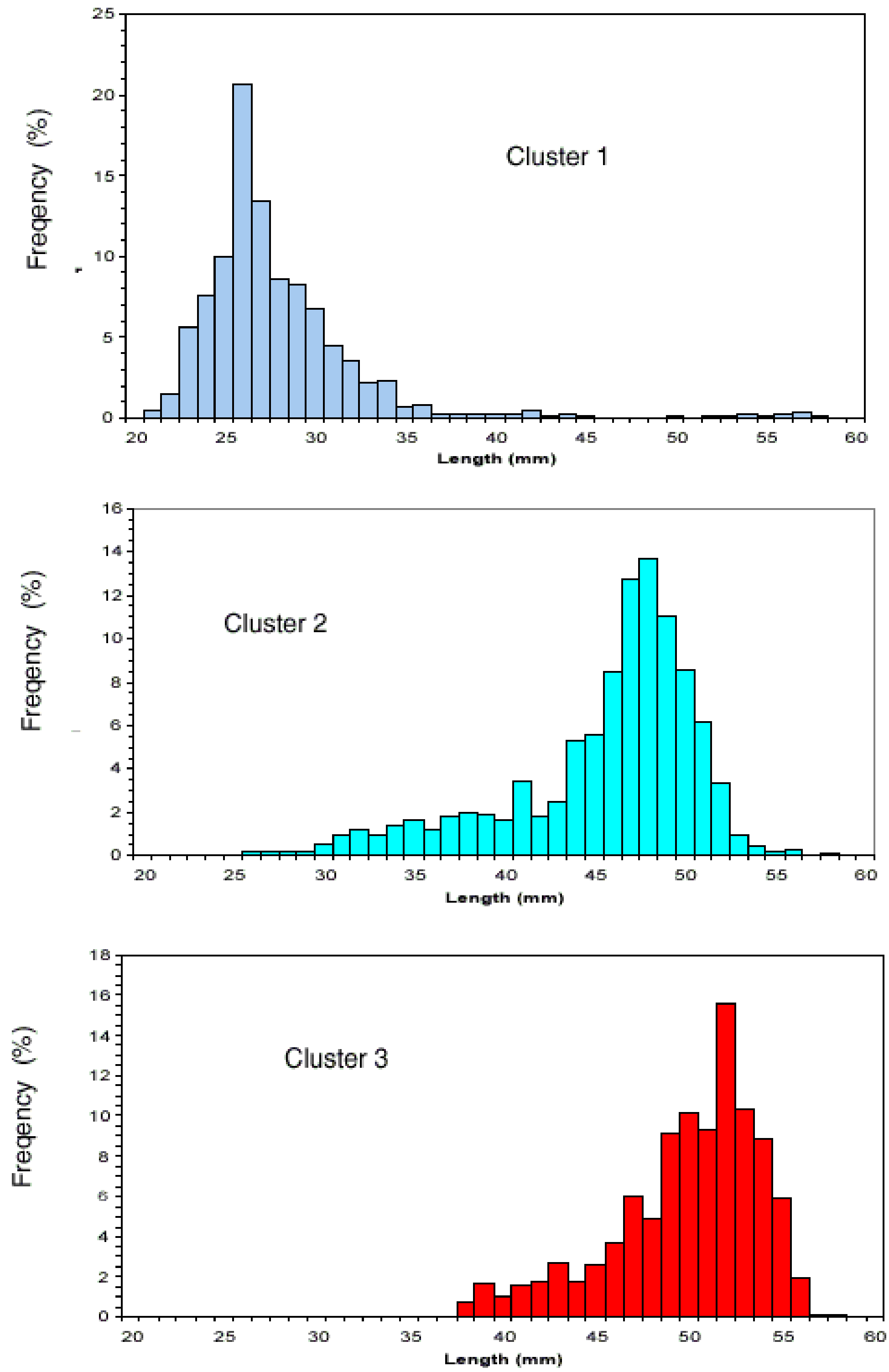

Figure 4: Aggregated length-frequency distributions of krill, from RMT8 samples, for the three clusters shown in Figure 3.

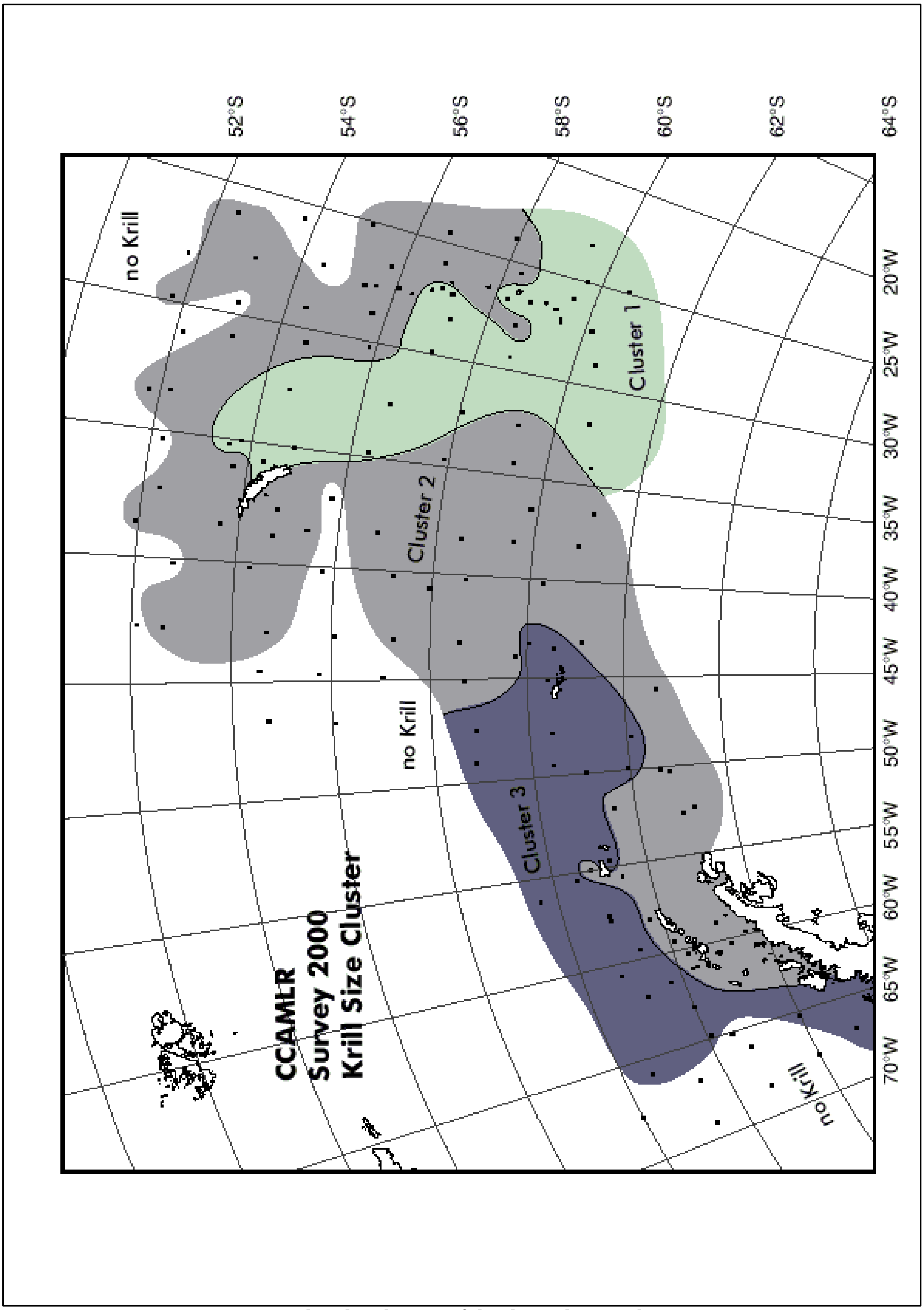

Figure 5: Geographic distribution of the three clusters shown in Figure 3.

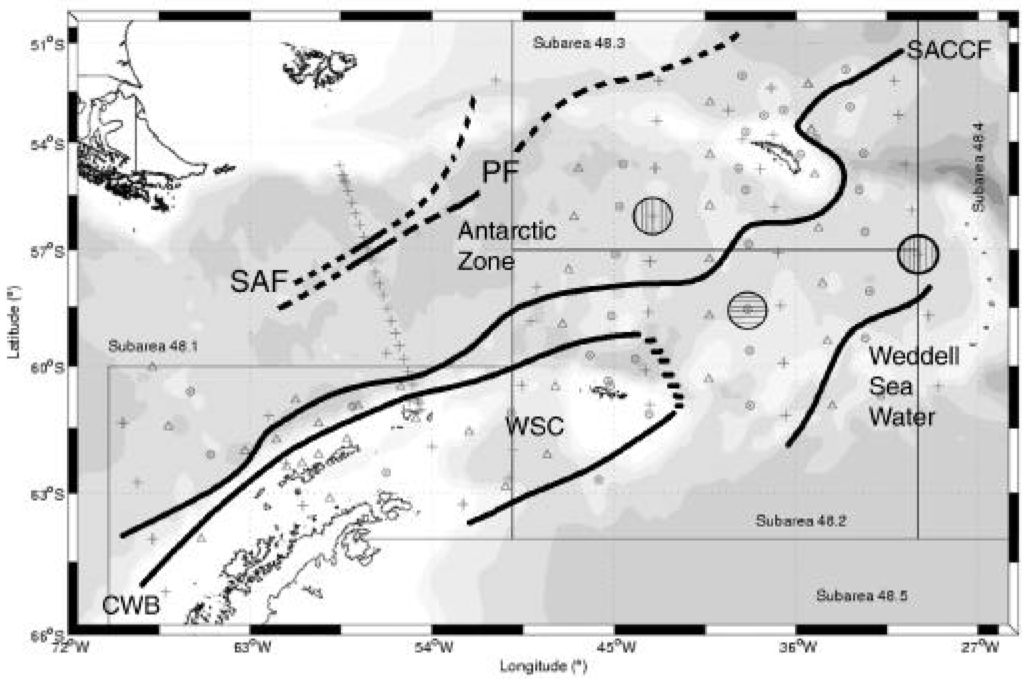

Figure 6: General distribution of water masses in the Scotia Sea and Antarctic Peninsula region during the CCAMLR-2000 Survey, based on CTD data collected by the *James Clark Ross* (+), *Yuzhmorgeologiya* (?) and *Kaiyo Maru* (?). Circles with vertical hatching represent eddies of warm water, horizontal hatched circles eddies of cold water. CWB: Continental Water Boundary; PF: Antarctic Polar Front; SACCF: Southern Antarctic Circumpolar Current Front; SAF: Sub-Antarctic Front; WSC: Weddell-Scotia Confluence.

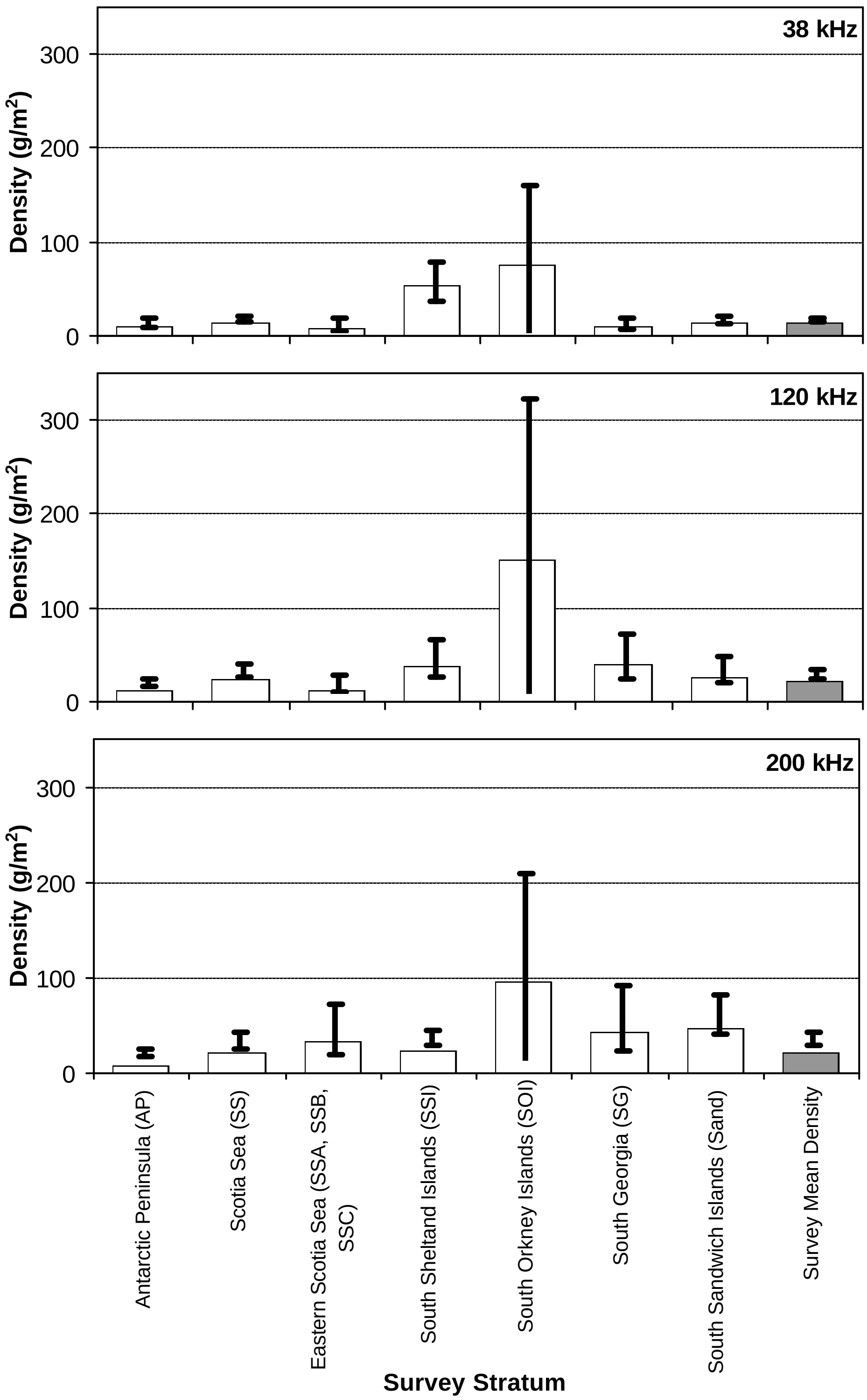

Figure 7: Mean krill density (g/m^2) by stratum, and for the entire survey area, estimated from acoustic data collected at 38, 120 and 200 kHz. Error bars represent the 95% confidence intervals.

ATTACHMENT A

LIST OF PARTICIPANTS

B_0 Workshop
(La Jolla, USA, 30 May to 9 June 2000)

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ATTACHMENT B

AGENDA

B_0 Workshop
(La Jolla, USA, 30 May to 9 June 2000)

1. Introduction (Day 1)

   1.1 Discussion of, and agreement to, the terms of reference, the specific tasks to be conducted, timetable, and output of workshop.
   1.2 Description of local facilities and infrastructure for accessing datasets and using analytical tools.
   1.3 Description of data preparations.

2. Abstracts of Survey Results (Day 1)

   2.1 Overviews of CCAMLR-2000 Survey by coordinators from Japan, UK, Russia and USA.
   2.2 Brief overviews of national surveys conducted in 1999/2000 over portions of the CCAMLR-2000 Survey area.
   2.3 Overviews of krill length frequency and water mass boundaries observed during CCAMLR-2000 Survey.

3. Methodology (Day 2)

   3.1 Presentation and discussion of methods for delineating krill volume backscattering from all other.
   3.2 Presentation and discussion of methods for converting krill volume backscattering to krill biomass density.
   3.3 Presentation and discussion of methods for estimating krill biomass over entire survey area.
   3.4 Presentation and discussion of methods for estimating variance of krill biomass estimate.
   3.5 Overview of Echoview 2.00.

4. Work Organisation (Day 2)

   4.1 List of specific tasks, designation of subgroups and assignment of responsibilities.
   4.2 Appointment of subgroup coordinators and rapporteurs.
   4.3 Outline format and content of report.
   4.4 Delegate work for writing sections and generating graphs.

5. Periodic Presentation and Discussion of Results from the Subgroups (Day 3 to Day 7).

6. Assemble Report (Day 8)

   6.1 Outline format and content of report.
   6.2 Delegate work for writing sections and generating graphs.
   6.3 Write report.

7. Adopt Report (Day 9).

ATTACHMENT C

CCAMLR B_0 ANALYSIS WORKSHOP SUBGROUP ON NET SAMPLING

Drs S. Kawaguchi (Japan), V. Siegel (Germany) and J. Watkins (UK) met to discuss the planned analysis of the RMT samples collected during the CCAMLR-2000 Survey.

2. Dr Watkins reported that all the RMT8+1 samples collected on board the *Yuzhmorgeologiya*, *James Clark Ross*, *Atlantida* and *Kaiyo Maru* had just returned to Cambridge, UK, on British Antarctic Survey ships. Basic sorting of RMT1 samples had been carried out on board the *Yuzhmorgeologiya*, but only sample volume had been determined on board the other ships. However, there had been no time to inspect the sample boxes prior to this workshop. Mr P. Ward (UK) will start the basic analysis of the unsorted RMT1 samples this summer and he estimates that this task will take around nine months. The data will then be made available to the CCAMLR participants, possibly through a future data analysis workshop.

3. It was re-emphasised that the zooplankton and krill samples collected during the CCAMLR-2000 Survey were extremely valuable, representing the largest single set of samples collected since the days of the Discovery Expeditions (1920–1930). It was therefore very important that the integrity of this dataset should be maintained while at the same time maximising the research that could be carried out on such samples.

4. It was recognised that the basic sorting of the RMT1 samples would separate the main species or groups of zooplankton but that there would be scope for more detailed analyses of individual taxa. Therefore it was likely that experts either within or outside the CCAMLR community will request access to the actual samples to undertake such work. For instance, interest in krill larvae (Dr Siegel) and salps (Dr Kawaguchi) had already been expressed. While such work should be welcomed it was important that this should take place within an agreed framework that protected the integrity of the samples and also the rights of the data originators. The latter was probably taken care of with the rules for access and use of CCAMLR data but the integrity of samples should be addressed through a set of 'conditions of access'.

5. A draft set of conditions of access was produced:

(i) Samples would only be released for further analysis if data originators from each country agreed.

(ii) Priority for analysis should be given to data originators, then other members of the CCAMLR community and finally requests originating outside of CCAMLR.

(iii) Persons requesting samples would have to guarantee return of entire samples to the archive within the agreed time.

(iv) All data from such analysis would have to be copied to the CCAMLR Data Centre and each data originator.

(v) All further analyses and publications would need approval of data originators.

6. In respect of the above, a general condition of access to samples should be to the account of the party wishing such access. As a consequence all costs associated with accessing the samples, processing the samples, and ensuring that their safety or integrity is not compromised will be borne by the accessing party. This will require that CCAMLR formalise the status of the samples and delineate a process for their use.

7. It was recognised that at present there were no firm plans to analyse the RMT8 samples further. However, a request had already been received from outside the CCAMLR community to look at the taxonomy and feeding ecology of myctophid fish. Any requests would need to take into account the stipulations of the draft conditions of access.

8. The particular case of samples of krill collected for genetic analyses was discussed. The collection of such samples had been agreed as part of the zooplankton sampling protocols. It was therefore thought appropriate that the idea of holding such samples centrally and sending subsamples for analysis to various groups should be considered. In the light of this discussion it was thought appropriate that clarification should be sought from the data originator (Dr B. Bergström, Sweden) about the status of genetic samples collected by the *Yuzhmorgeologiya.*

ATTACHMENT D

DESCRIPTORS FOR SUMMARY TABLES CONTAINING BIOMASS ESTIMATES

The following descriptors relate to labels contained in Tables 24 to 26. It should be noted that the various descriptor functions are based on those given in Jolly and Hampton (1990). In the formulae below *i* is used to index intervals along a transect, *j* is used to index transects within a stratum, and *k* is used to index strata.

Transect Label	Formula /Descriptor
Length	Transect length defined as the sum of all interval weightings (as defined in paragraph 3.51) $L_j = \sum_{i=1}^{N_j} (W_I)_i$ where L_j is the length of the *j*th transect, $(W_I)_i$ is the interval weighting of the *i*th interval, and N_j is the number of intervals in the *j*th transect.
Weighting factor	Normalised transect length $w_j = \dfrac{L_j}{\frac{1}{N_k}\sum_{j=1}^{N_k} L_j}$ such that $\sum_{j=1}^{N_k} w_j = N_k$ where w_j is the weighting factor for the *j*th transect, and N_k is the number of transects in a stratum.
Krill density measured	Mean areal krill biomass density over all intervals on each transect $\bar{\rho}_j = \dfrac{1}{L_j}\sum_{i=1}^{N_j} S_{Ai} f_i (W_I)_i$ where $\bar{\rho}_j$ is the mean areal krill biomass density on the *j*th transect, S_{Ai} is the integrated backscattering area for the *i*th interval and f_i is the conversion factor for the *i*th interval (see paragraphs 3.28 to 3.52).
Krill density weighted	Mean areal krill biomass density times the weighting factor $\bar{\rho}_{wj} = w_j \bar{\rho}_j$ where $\bar{\rho}_{wj}$ is the mean weighted areal krill biomass density on the *j*th transect.
Variance component	$VarComp_j = w_j^2 \left(\bar{\rho}_j - \bar{\rho}_k\right)^2$ where $VarComp_j$ is the weighted contribution of the *j*th transect to the stratum variance.

Stratum Label	Formula/Descriptor
Mean	Stratum mean areal krill biomass density $\bar{\rho}_k = \frac{1}{N_k}\sum_{j=1}^{N_k} w_j \bar{\rho}_j$ where $\bar{\rho}_k$ is the mean areal krill biomass density in the kth stratum (after equation 1, Jolly and Hampton, 1990).
Variance	Stratum variance $Var(\bar{\rho}_k) = \frac{N_k}{N_k - 1} \frac{\sum_{j=1}^{N_k} w_j^2 (\bar{\rho}_j - \bar{\rho}_k)^2}{\left(\sum_{j=1}^{N_k} w_j\right)^2} = \frac{\sum_{j=1}^{N_k} w_j^2 (\bar{\rho}_j - \bar{\rho}_k)^2}{N_k (N_k - 1)}$ where $Var(\bar{\rho}_k)$ is the variance of the mean areal krill biomass density in the kth stratum.
CV (%)	Coefficient of variation $CV_k = 100 \frac{(Var(\bar{\rho}_k))^{0.5}}{\bar{\rho}_k}$ where CV_k is the coefficient of variation for the kth stratum.

Survey Label	Formula/Descriptor
Nominal area	Area of kth stratum (A_k) estimated at the time of survey design (see paragraphs 2.2 and 2.3).
Mean density	Mean areal krill biomass density of the kth stratum, $\bar{\rho}_k$.
Area*density	$A_k \bar{\rho}_k$
Variance component	$VarComp_k = A_K^2 Var(\bar{\rho}_k)$ where $VarComp_k$ is the contribution of the kth stratum to the overall survey variance of B_0.
Mean density	Overall survey mean areal krill biomass density $\bar{\rho} = \frac{\sum_{k=1}^{N} A_k \bar{\rho}_k}{\sum_{k=1}^{N} A_k}$ where N is the number of survey strata (after equation 2, Jolly and Hampton, 1990).

Survey Label (continued)	Formula/Descriptor
Variance	Overall survey variance of the mean areal krill biomass density $$Var(\bar{\rho}) = \frac{\sum_{k=1}^{N} A_k^2 Var(\bar{\rho}_k)}{\left(\sum_{k=1}^{N} A_k\right)^2} = \frac{\sum_{k=1}^{N} VarComp_k}{\left(\sum_{k=1}^{N} A_k\right)^2}$$ (after equation 3, Jolly and Hampton, 1990).
CV	Overall coefficient of variation of the mean areal krill biomass density $$CV_{\bar{\rho}} = 100 \frac{\left(Var(\bar{\rho})\right)^{0.5}}{\bar{\rho}}$$
Krill standing stock	$$B_0 = \sum_{k=1}^{N} A_k \bar{\rho}_k$$
Variance	Overall survey variance of B_0 $$Var(B_0) = \sum_{k=1}^{N} VarComp_k$$
CV	Overall coefficient of variation of B_0 $$CV_{B_0} = 100 \frac{\left(Var(B_0)\right)^{0.5}}{B_0}$$