ANNEX 5

REPORT OF THE FIFTH MEETING OF THE SUBGROUP ON ACOUSTIC SURVEY AND ANALYSIS METHODS

(Cambridge, UK, 1 to 4 June 2010)

CONTENTS

REPORT OF THE FIFTH MEETING OF THE SUBGROUP ON ACOUSTIC SURVEY AND ANALYSIS METHODS

(Cambridge, UK, 1 to 4 June 2010)

INTRODUCTION

1.1 The fifth meeting of the Subgroup on Acoustic Survey and Analysis Methods (SG-ASAM) was held at the British Antarctic Survey (BAS), Cambridge, UK, 1 to 4 June 2010. The Convener, Dr J. Watkins (UK), welcomed participants (Appendix A) on behalf of the hosts and outlined local arrangements for the meeting.

1.2 The terms of reference for the meeting focused on the estimation of krill (*Euphausia superba*) biomass (B_0) in Area 48 and particularly on the reanalysis of the acoustic data from the CCAMLR-2000 Survey (Appendix B).

1.3 The original calculation of B_0 arising from the CCAMLR-2000 Survey was undertaken at the B_0 Workshop held in La Jolla, USA, in May 2000 (SC-CAMLR-XIX, Annex 4, Appendix G). Since then there have been changes to CCAMLR's recommended protocols for assessing krill target strength (TS) and identifying acoustic targets. As a result, there have been a number of separate recalculations of the data from the CCAMLR-2000 Survey which have generated a number of different biomass estimates.

1.4 In order to complete the reanalysis requested by the Scientific Committee, the following set of analytical steps was identified for SG-ASAM in 2010:

Prior to the meeting –

1. review of the existing calculations of B_0, and associated uncertainty, to clarify issues relevant to reanalysis;
2. confirm the steps of the new analysis to be undertaken by Members;
3. confirm the validity of the acoustic data and ancillary datasets required for model parameterisation;
4. Members to undertake independent calculations of B_0 using the agreed procedures;

At the meeting –

5. review all documented results of stages 1, 2, 3 and 4 submitted to SG-ASAM;
6. discuss results and add clarification to protocols if necessary;
7. agree a validated B_0 estimate and associated uncertainty and submit the results to the 2010 meeting of WG-EMM.

1.5 The work prior to the meeting was conducted by a Correspondence and Analysis Group. The membership of that group was open to all CCAMLR Members (SC CIRC 10/7), and consisted of Dr L. Calise* (Norway), Mr A. Cossio* (USA), Drs S. Fielding* (UK), S. Kasatkina (Russia), S. Kawaguchi (Australia), T. Knutsen (Norway), R. Korneliussen (Norway), R. O'Driscoll (New Zealand), D. Ramm* (Data Manager), K. Reid* (Science Officer), C. Reiss* (USA), G. Skaret* (Norway), Mr Y. Takao* (Japan), Drs J. Watkins* (Convener), G. Watters* (USA) and X. Zhao* (China). The group's correspondence and data were archived on the CCAMLR website and are available from the Secretariat. Those members of the Correspondence and Analysis Group who attended the meeting are indicated by an asterisk.

1.6 The meeting's provisional agenda was discussed and adopted without change (Appendix C).

1.7 This report was prepared by meeting participants. Sections of the report dealing with advice to the Scientific Committee are highlighted (see also 'Advice to the Scientific Committee').

REANALYSIS OF CCAMLR-2000 SURVEY DATA

2.1 The intersessional work conducted by Members covered a wide range of topics, and contributions to the meeting were provided by scientists from Japan, Norway, UK and the USA. Document numbers were not assigned to any of the material developed in preparation for the meeting, but all such material was provided to the Subgroup and used in its discussions. All material prepared for or during the meeting was lodged with the Secretariat.

2.2 The Subgroup agreed to consider Agenda Items 2.1 and 2.2 in parallel, and based discussions on whether and how to revise or modify implementation of protocol for estimating B_0 (Item 2.2), hereafter simply referred to as the protocol, from its review of work undertaken during the intersessional period (Item 2.1).

2.3 The Subgroup noted that its review and, if necessary, revision of how the protocol is implemented should be independent of any actual estimates of B_0 and agreed that it would only compute an estimate of B_0 after it had agreed to all elements of the protocol's implementation.

2.4 The Subgroup reviewed the outline of the protocol provided in SC-CAMLR-XXVIII, Annex 8, Appendix E, and noted that the focus of its work would relate primarily to acoustic data processing and analysis, echo integration, conversion of acoustic backscatter to area biomass estimate, estimation of total biomass from biomass density and estimation of sampling errors. A table identifying issues requiring discussion relating to these topics had been circulated by the Convener during the intersessional period (Table 1), and the rows of this table were used to structure ensuing discussions (these row names thus form a basis for the subsection headings below).

2.5 The terms of reference for the meeting of SG-ASAM called, *inter alia*, for Members to confirm steps of analysis by correspondence and review independent calculations of B_0 (SC-CAMLR-XXVIII, Annex 11) provided by Members. Substantive discussion occurred by correspondence (and is recorded on the SG-ASAM section of the CCAMLR website), this identified a number of issues. Some of these were not resolved prior to the meeting, and, therefore, independent estimates of B_0 were not available for review prior to the meeting.

2.6 The Subgroup noted that Members had independently conducted various confirmatory analyses and reviewed or prepared a substantial amount of the computer code needed to evaluate implementation of the SDWBA protocol and estimate B_0 (SC-CAMLR-XXVIII, Annex 4, paragraph 3.82). By discussing the confirmatory analyses, testing the independently developed pieces of computer code, and cross-checking such code among Members, the Subgroup agreed it should be able to provide a validated estimate of B_0.

Identify set of Echoview files

2.7 The Subgroup verified that all participants possessed the same set of files (distributed as a set of CDs after the CCAMLR-2000 Survey data were originally analysed in 2000) that are used within Echoview to conduct necessary pre-processing such as noise reduction and calibration, and also apply the δS_v target identification windows (these are .ev files). Building on intersessional work conducted by Dr Fielding and Mr Cossio, all these data files were reviewed by the Subgroup and several issues (e.g. inconsistent file names, incorrect binning, integration of bottom echoes) were identified and corrected. Three files were edited at the meeting: Sand06-Atl.ev, SG01-Yuz.ev and SSI01-KyM.ev. A spreadsheet describing changes made to all data files was lodged with the Secretariat.

Identify set of .csv files

2.8 After correcting the .ev files for issues identified above (paragraph 2.7), the Subgroup exported a new set of .csv files from Echoview. These .csv files contained data binned in 5 m (depth) by 50-ping interval (equivalent to a horizontal distance of approx. 500 m at 10 knots) and were exported without application of a target identification filter (paragraph 2.36). All these .csv files were lodged with the Secretariat (see documentation for filename convention, paragraph 3.2).

Identify the length probability density functions

2.9 The Subgroup agreed that the cluster-specific length probability distribution functions provided in the file LFD 2000 Cluster.xls were correct and could be used to estimate B_0. These probability density functions are used to generate conversion factors (paragraph 2.38) that translate length-frequency data to biomass. A copy of the .xls file was lodged with the Secretariat, and the Subgroup considered the data contained in the file while conducting its work.

Determine which SDWBA model to use

2.10 The Subgroup discussed whether B_0 should be calculated on the basis of the full SDWBA model or the simplified SDWBA model. It was noted that the parameters of the simplified model will change if key parameters in the full model (e.g. parameters describing the orientation distribution, shape etc.) are themselves changed. It was also noted that fitting the simplified model to output from the full model adds error to the characterisation of TS. Nevertheless, the simplified model can more easily be implemented by non-specialists and, notably, its use is a specified element of the protocol.

2.11 The Subgroup agreed to compute estimates of B_0 using both the full model and the simplified model. The Subgroup noted that the former estimate would likely be preferred on a scientific basis, but acknowledged that the latter estimate is required by application of the protocol.

Define parameters to initialise SDWBA

2.12 The Subgroup reviewed the parameter values provided in Table 2 from the 2009 report of SG-ASAM (SC-CAMLR-XXVIII, Annex 8) and recalled its previous view that in the absence of information about the accuracy of the krill mass density and sound-speed measurements, it should not change the default values for the density contrast *g* and the sound-speed contrast *h* currently in place when calculating krill biomass (SC-CAMLR-XXVIII, Annex 8, paragraph 19). The Subgroup also came to this conclusion regarding the fatness coefficient and the sound speed in seawater *c*. Despite accepting all these parameter values at present, the Subgroup acknowledged that future work to address remaining uncertainties in these parameters would be useful (see Item 4).

2.13 The Subgroup agreed, however, that the parameters defining the orientation distribution (reported as $N(11°,4°)$ for the 'mean' case in SC-CAMLR-XXVIII, Annex 8, Table 2) would need to be revised. A revision of the orientation distribution was deemed necessary because, during the course of intersessional review and correspondence by Members, several issues were identified in the Matlab code previously used to implement the full SDWBA (the Matlab package named 'SDWBApackage20050603'). It was noted that these issues were present, but unidentified, in the code used to estimate B_0 at the 2007 meeting of WG-EMM. Drs Calise and Skaret provided a document titled 'Verification and investigation of the krill target strength prediction of the SDWBApackage20050603', that described the problems identified intersessionally; the document also proposed some solutions. Problems with the previous implementation of the full SDWBA included:

(i) incorrect position vector *r* and ensemble of radii values *a* delineating the shape of the standard generic krill (McGehee et al., 1998);

(ii) incorrect reference length applied when scaling krill with lengths different than the 'standard' length of 38.35 mm;

(iii) inappropriate resampling of the position vector *r* needed for frequencies higher than 120 kHz.

2.14 The first error (an error in the 'shape file') seems to originate from a confusion between the measured length of the generic krill presented in McGehee et al. (1998) (38.35 mm AT length, front of the eyes to tip of the telson, see Morris et al., 1988) (denoted '*L*' in SC-CAMLR-XXIV, Annex 6, paragraph 11(i)) and the maximum digitised values in the x-dimension of the r_0 vector describing that shape (the digitised length equal to 41.09 mm) (denoted '*l*' in SC-CAMLR-XXIV, Annex 6, paragraph 11(ii)). The body shapes used in SDWBApackage20050603 and provided by McGehee et al. (1998) are given in Table 2 and visualised in Figure 1. The Subgroup agreed to revise the shape file for implementing the full SDWBA by using the correct information from McGehee et al. (1998). The revised shape file was lodged with the Secretariat.

2.15 In SDWBApackage20050603 lengths other than the standard length are scaled using the maximum value of digitised shapes from McGehee et al. (1998) as the point of reference (the digitised x-length equal to 41.09 mm, *l*, rather than the measured standard length of 38.35 mm, *L*). Based on advice provided by Drs Calise and Skaret, the Subgroup agreed that the scaling factor should, however, be based on the standard length *L* itself, and the Matlab script named ‘ProcessKrillEsupSDWBATS.m’ was revised accordingly. The revised script was lodged with the Secretariat.

2.16 Comparable predictions between frequencies from the full SDWBA model require that the spatial resolution of the discrete cylinders describing the shape relative to the ratio between the krill length and the acoustic wavelength is kept constant. Thus, for frequencies higher than the reference frequency (120 kHz), krill shape needs to be re-characterised by adjusting the number of cylinders and the inter-element phase variability. Drs Calise and Skaret determined that the implementation of the position vector resampling, which depended on the Matlab function ‘resample.m’ (from Matlab’s Signal Processing Toolbox), produced points that did not follow the central body line according to the digitised standard krill.

2.17 Evidence for the problematic implementation of the ‘resample.m’ function is provided in Figure 2. The resampled shape was shown to have a greater length than the original shape (these lengths should be equal) and was partly composed of cylinders that were orientated in unnatural directions. The Subgroup determined that the effect of the resampled shape on TS prediction was peaks in TS at incidence angles of about 130°–160° and 190°–220° (Figure 2); this effect was not considered to be consistent with acoustical theory. The Subgroup also noted that resample.m implements a deterministic sampling process that, in this application, is length-independent; thus, all re-characterised body shapes predicted by SDWBApackage20050603 will have shapes that are incorrect and identical to the resampled shape illustrated in Figure 2.

2.18 The Subgroup discussed possible methods to revise the process for re-characterising krill size at frequencies above 120 kHz and agreed to attempt using alternative techniques such as a cubic smoothing spline to interpolate centre positions for cylinders located along the central body line and related radii. As a first approximation, application of the simple cubic spline only on the position vector, retaining the resample.m function for the radii values, was shown to provide a much improved characterisation of krill shape, although all cylinders comprising the new shape had equal width, thus not following the requirement of a constant cylinder length to wavelength ratio (SC-CAMLR-XXIV/BG/3, Equations (6) and (7), Conti and Demer, 2006). The spline-based characterisation of shape at frequencies above 120 kHz was also shown to remove the higher TS levels at incidence angles outside the main scattering lobe, thus making predictions of TS from the re-characterised shape more consistent with acoustical theory (Figure 3). Importantly, the spline-based characterisation of shape was also considered to provide reasonable predictions of TS in the main scattering lobe (Figure 3).

2.19 Given the results presented in Figures 2 and 3, the Subgroup agreed to implement the spline procedure in the full SDWBA model, and code in the Matlab script named ‘BSTS_SDWBA.m’ was revised accordingly. The revised script was lodged with the Secretariat.

Determine number of model scenarios to run

2.20 The Subgroup agreed that, given the time available to run the full SDWBA model and compute estimates of B_0, the model scenarios considered at the meeting would be limited to include those based on the mean values and values for ±1 SD of fatness coefficient, *g*, *h* and *c* listed in SC-CAMLR-XXVIII, Annex 8, Table 2. Thus, a total of three scenarios would be run. The Subgroup also agreed to compute new values for the three orientation distributions required by these scenarios, noting that these new orientation distributions would be computed following the procedures outlined in paragraphs 2.21 to 2.29. Table 3 contains parameter values used to run all three scenarios with the full SDWBA model.

Determine availability of method for calculating the orientation

2.21 Conti and Demer (2006) estimated parameters of the orientation distribution by a least-squares 'inversion' of the full SDWBA model. SDWBApackage20050603 does not provide the computer code needed to conduct this inversion, but Dr Fielding provided the Subgroup with Matlab code designed to perform this task. The Subgroup conducted an extensive review of the code provided by Dr Fielding, including line-by-line analyses of the code itself and viewing an extensive variety of diagnostic plots, and concluded that the new code would provide results comparable to those illustrated in Conti and Demer (2006). The Subgroup therefore agreed to implement the inversion code provided by Dr Fielding in its estimation of B_0; this code was lodged with the Secretariat.

Identify number of required orientation distributions

2.22 The Subgroup agreed that a single orientation distribution should be derived for the whole survey area rather than for each krill length-frequency cluster (as identified in Siegel et al., 2004). This continued the approach used in previous estimations of B_0 (e.g. Conti and Demer, 2006; WG-EMM-07/30 Rev. 1).

2.23 To undertake the inversion to estimate an orientation distribution, a prediction of δS_v ($S_{v120kHz-38kHz}$), derived from the SDWBA model solved with the krill length-frequency distribution for the entire survey area, is required. The Subgroup noted that krill length-frequency distributions for each cluster were held by the Secretariat, however, the Subgroup agreed that a length-density distribution for the entire survey (Figure 6 in Siegel et al., 2004) was the most appropriate dataset to use. This dataset was obtained from Dr Siegel during the meeting and was lodged with the Secretariat.

Identify method of inversion

2.24 The Subgroup agreed to use the least-squares inversion code described in paragraph 2.21 and fit to δS_v ($S_{v120kHz-38kHz}$) binned in 1 dB increments. These δS_v values were developed by predicting TS from the full SDWBA model using the length-frequency data selected in paragraph 2.23.

Identify range of orientations (mean, SD) that inversion is to be applied over

2.25 The Subgroup agreed to invert the full SDWBA for all orientation distributions with means incrementing in 1° degree steps between +45° and –45° and SD incrementing in 1° degree steps between 1° and 50°. Searching through the results from these inversions to find the orientation distribution that minimised the sum of squared differences between δS_v predicted from observed length frequencies (paragraph 2.23) and δS_v predicted by the full SDWBA provided the 'mean' orientation recorded in Table 4.

Identify which acoustic data to apply the inversion process to

2.26 The Subgroup noted that Demer and Conti (2005), and Conti and Demer (2006) applied the inversion to acoustic data only from the RV *Yuzhmorgeologiya*. The Subgroup agreed that the inversion process should be applied to the complete acoustic dataset.

Identify method for correcting sample-averaging effect on orientation variance

2.27 SC-CAMLR-XXVIII, Annex 8, paragraph 35, points out that the inversion to derive orientation is carried out using measurements of S_v averaged over 50 pings and 5 m depth intervals. This averaging process reduces the variance by the inverse of the number of independent observations within the averaging interval. Given that there were 50 pings, and hence 50 independent acoustic samples within each averaging interval, the Subgroup agreed that the SD derived directly from the inversion process should be multiplied by $\sqrt{50}$ to obtain a corrected SD.

2.28 The Subgroup suggested that, in the future, the SD derived from the inversion process should be called the standard error prior to using the averaging interval correction and should only be referred to as the SD after applying the correction.

2.29 SC-CAMLR-XXVIII, Annex 8, paragraph 35, additionally recommended that corrections to the orientation variance should also take account of the mean number of krill within the sampling volume. The Subgroup considered how such an additional correction might be applied. Using an acoustic estimate of krill number introduces a further circularity within the estimation process, and available density estimates of 14–18 g m^{-2} from net sampling (Siegel et al., 2004), produce correction factors close to 1. The Subgroup agreed therefore that for this analysis no correction for number of krill in the sampling volume would be applied.

Identify length-frequency data to calculate δS_v windows for target identification

2.30 The Subgroup discussed how it would subset the available length-frequency data to develop δS_v windows for target identification. It was acknowledged that the protocol is somewhat unclear because it simultaneously requires that the subset includes ≥95% of the krill-length probability density function and achieve the smallest δS_v window (SC-CAMLR-XXVIII, Annex 8, Appendix E). In particular, it was not clear whether the intent of the protocol was that the tails of the length probability density function be symmetrically eliminated (e.g. 2.5% on either side of the mean if selecting 95% of the length probability density function) or to preferentially eliminate observations from one tail over the other (e.g. with the intent to constrain the δSv windows to the smallest range). The Subgroup felt that including 99% of the krill probability density function would be more likely to include targets that should be identified as krill (particularly small targets), but including 99% of the krill probability density function would not minimise the size of the δSv windows. While it was acknowledged that '10 mm length classes could be refined [e.g. reduced to 1 mm] to reduce uncertainty' (SC-CAMLR-XXVIII, Annex 8, paragraph 38), the Subgroup also felt that 10 mm windows would be preferable to 1 mm windows. The former window size would allow for krill to be identified acoustically that may have not been captured in the nets. The Subgroup agreed to apply the >95% window in 10 mm bins.

Identify method to create δS_v windows

2.31 The Subgroup discussed whether δS_v windows should be generated from the minimum and maximum krill sizes caught in the net samples or the minimum and maximum dB ranges across the size range of krill sampled. It was agreed that the latter case was preferable since, between 120 and 200 kHz, sound scattering can be in the transition from the Rayleigh range to geometric range and therefore larger krill will not necessarily generate smaller windows.

2.32 The Subgroup recalled the need to revise the parameters of the orientation distribution (paragraphs 2.13 and 2.20) and recognised that this revision would necessitate revision of the δS_v windows that were previously used to identify krill targets (see SC-CAMLR-XXIV, Annex 6, Table 3). The Subgroup therefore agreed to conduct this revision; updated values for δS_v windows used in this analysis are reported in Table 4.

Determine whether two-frequency and three-frequency identification techniques should be applied to the data

2.33 The Subgroup noted that the protocol requires target identification based on three frequencies.

2.34 The Subgroup further noted that negative δS_v values might be estimated from TS models for 120 and 38 kHz, and was concerned that three-frequency target identification may filter out targets that are known to be krill or likely to be krill, particularly when the SD of the orientation distribution is small, and that this may be addressed by validation of target identification (see paragraph 4.1(vii)).

Apply target identification to dataset

2.35 The Subgroup agreed to apply all target identification methods to data binned by 5 m and 50 pings.

Integrate data in 1 n mile resets

2.36 The Subgroup agreed that, as the new target identification windows (see Table 4) would be applied in Echoview, then the integration of data into 1 n mile resets would also be undertaken as part of the Echoview processing prior to exporting a final set of Echoview .csv files that would contain the volume backscatter data for targets only attributed to krill (see documentation for filename convention, paragraph 3.2).

Apply latitude correction to data

2.37 The Subgroup noted that code for applying a latitude correction had been developed at the B_0 Workshop in June 2000. The Subgroup agreed that there was no need to change this code and that this step would be undertaken as described in SC-CAMLR-XIX, Annex 4, Appendix G, paragraph 3.51.

Generate conversion factors using length/weight/TS relationships

2.38 The Subgroup noted that a correction to the computation of conversion factors had been described in WG-EMM-07/30 Rev. 1 (Table 1). The Subgroup agreed to apply this correction.

Generate transect krill densities

2.39 The Subgroup processed the transect krill densities and the code used to do this was lodged with the Secretariat.

Generate B_0 estimates for each model run

2.40 Having agreed to all the revisions in the elements in the protocol implementation (paragraph 2.3), the Subgroup generated B_0 estimates with associated Jolly and Hampton CVs using the full SDWBA and the simplified SDWBA (Table 4).

2.41 Although the protocol suggested the use of the simplified model, the Subgroup advised that the output from the full SDWBA was preferred on a scientific basis because fitting the simplified model to results from the full model introduced additional errors and uncertainty into estimates of TS that could propagate through to errors in target identification (paragraph 2.10).

2.42 The Subgroup agreed that the intersessional work and model exploration conducted at this meeting had shown that the value for B_0 provided at the 2007 meeting of WG-EMM was incorrect and that the difference in that value and the value of B_0 from the full SDWBA provided during this meeting arose simply as a result of the correction of errors that were included in the calculation in 2007.

Exploration of uncertainty

2.43 The Subgroup noted that the process to produce the results presented in Table 4 were manually and computationally intensive and took 15 h to complete and that this limited the ability to explore the implications of changing key parameters (fatness coefficient, *h*, *g*, shape and orientation; see Table 3) on the estimation of B_0.

2.44 In the initial exploration of the ±1 SD scenarios (paragraph 2.20) the Subgroup recognised that the complex interactions involved meant that the '±1 SD' should not be considered as ±1 SD in the estimate of B_0. Therefore, the Subgroup agreed that to fully evaluate uncertainty in B_0, a probability density function of B_0 would be required (paragraph 4.1(viii)).

DOCUMENTATION OF THE ACOUSTIC PROTOCOLS

3.1 The Subgroup did not have an opportunity to consider the provision of additional documentation of the acoustic protocols but agreed that the documentation developed during the meeting and the changes to the protocol described in section 2 provided a sufficiently open and detailed description of the acoustic protocol and improvements made to it during 2010.

3.2 The documentation developed during the meeting was placed on the CCAMLR website and will be presented to WG-EMM.

FUTURE WORK

4.1 The Subgroup:

Methodological improvements –

(i) agreed that the protocol for orientation inversion currently provides no statistical indication of the goodness-of-fit between estimated δS_v ($S_{v120kHz-38kHz}$) values with distributions of orientation generated from model inversion and observed δS_v ($S_{v120kHz-38kHz}$) values;

(ii) agreed that the addition of the 70 kHz frequency should be encouraged (SC-CAMLR-XXVI, Annex 8, paragraphs 9 and 11), noting that krill backscattering at 70 kHz still falls in the Rayleigh scattering region and so comparisons with 38 and 120 kHz can be used to make inferences about krill size;

(iii) agreed on the importance of measurements of both *g* and *h* during acoustic surveys but recognised the practical difficulties of making measurements at-sea. However, given the relationship between *g* and *h*, *in situ* measurements and estimates of only one of these parameters may be useful in itself. The Subgroup recommended a strategy involving further land-based work to define simple classification of *g* and *h* based on maturity and sex stage to identify which investigations would be desirable and feasible to conduct at sea. The land-based work might include work on aquarium-held samples and laboratory measurements of biochemical composition;

(iv) encouraged further work to more appropriately define the shape and position of the discretised cylinders according to krill body shape and scattering properties, noting the potential for considerable differences in the acoustic properties of the carapace and thoracic segments;

(v) recognised that there remained some ambiguity as to whether the angle of orientation (θ) is related to the angle of acoustic incidence (φ) by $90 - \theta$ or $270 + \theta$ in the part of the Matlab code SDWBApackage20050603 used to determine the average orientation (Figure 4). However, analysis of the difference produced by using $90 - \theta$ or $270 + \theta$ with an $N(-20°,28°)$ orientation distribution indicated that the difference in average TS would be very small (Table 5);

(vi) suggested that the clarification of the relationship between of incidence angle (φ) and the orientation angle (θ) would be useful, especially in the context of the development of different representations of krill shape.

Validation of the target identification –

(vii) agreed that there was a need to validate the target identification procedure with *in-situ* data and recalled that it had suggested that a library of echograms validated by external verification, including target hauls, be assembled for this purpose (SC-CAMLR-XXVIII, Annex 8, paragraph 90(ii)).

Developments –

(viii) experience during the meeting with the range of possible sources of variability and the time taken to run the model iterations highlighted the need for efficient streamlined code that could be implemented in a Monte-Carlo simulation to produce a probability density function of B_0 estimates.

General –

(ix) acknowledged that, while continued improvements in the protocol were encouraged, the implications of changes in the protocol on the compatibility of existing time series of acoustic data should be considered during all such developments.

RECOMMENDATIONS TO THE SCIENTIFIC COMMITTEE

5.1 The Subgroup advice to the Scientific Committee is contained in paragraphs 2.40 to 2.44.

5.2 In addition, the Subgroup noted that an appropriate parameterisation of the revised protocol could be applied to acoustic survey data for krill from other areas where catch limits are in place and where those surveys were conducted in accordance with the CCAMLR-2000 Survey protocols.

ADOPTION OF REPORT

6.1 The report of the meeting was adopted.

CLOSE OF THE MEETING

7.1 Dr Watkins thanked all participants for their contributions and involvement in the meeting, including the preparatory work. The meeting had included an all-night session and the individual contributions were outstanding.

7.2 Dr Watters, on behalf of the Subgroup, thanked Dr Watkins for his expertise and guidance during the meeting. The Subgroup also thanked Mr Cossio and Drs Fielding and Reiss for their expertise in conducting the complex and computationally intensive model runs.

7.3 The meeting was closed.

REFERENCES

Conti, S.G. and D.A. Demer. 2006. Improved parameterization of the SDWBA for estimating krill target strength. *ICES J. Mar. Sci*., 63 (5): 928–935.

Demer, D.A. and S.G. Conti. 2005. New target-strength model indicates more krill in the Southern Ocean. *ICES J. Mar. Sci*., 62 (1): 25–32.

Hewitt, R.P., J. Watkins, M. Naganobu, V. Sushin, A.S. Brierley, D. Demer, S. Kasatkina, Y. Takao, C. Goss, A. Malyshko, M. Brandon, S. Kawaguchi, V. Siegel, P. Trathan, J. Emery, I. Everson and D. Miller. 2004. Biomass of Antarctic krill in the Scotia Sea in January/February 2000 and its use in revising an estimate of precautionary yield. *Deep-Sea Res. II*, 51: 1215–1236.

McGehee, D.E., R.L. O'Driscoll and L.V. Martin Traykovski. 1998. Effect of orientation on acoustic scattering from Antarctic krill at 120 kHz. *Deep-Sea Res. II*, 45 (7): 1273–1294.

Morris, D.J., J.L. Watkins, C. Ricketts, F. Buchholz and J. Priddle. 1988. An assessment of the merits of length and weight measurements of Antarctic krill *Euphausia superba*. *Brit. Antarc. Sur. Bull.*, 79: 27–50.

Siegel, V., S. Kawaguchi, P. Ward, F. Litvinov, V. Sushin, V. Loeb and J. Watkins. 2004. Krill demography and large-scale distribution in the southwest Atlantic during January/February 2000. *Deep-Sea Res. II*, 51 (12–13): 1253–1273.

Table 1: Issues considered by SG-ASAM during preparatory work.

Step	Task	Proposed community action	Query
Data			
1	Identify set of Echoview files to work from	The community to agree that all Echoview processing steps undertaken in 2000 were correct.	
1.a	Identify set of .csv files to work from	The community to agree a set of working files.	(1) For those nations working in Matlab (or external to Echoview for target identification) it would be useful to use just one set of agreed .csv files (per frequency) of calibrated data (with no target id mask applied). (2) Data exported should be in 50 pings by 5 m exports to conform with original id method. (3) If above (2) then new method (code) will be needed to resample from 50 pings to 1 n mile after target identification, outside of Echoview.
2	Identify the length probability density functions (for each cluster and total) to use	The community to agree on one set of length probability density functions.	(1) Have all the errors been found in the length frequency data?
3	Make available to the community	CCAMLR to set up FTP site of all up-to-date files.	
SDWBA model			
4	Determine which SDWBA model equation to use and who has access	Community to agree the use of the full SDWBA model rather than creating a new set of simplified coefficients.	(1) Do all nations have the required code? (2) Can we make the code available?
5	Define parameters to initialise SDWBA	Community to agree on using parameters from SC-CAMLR-XXVIII, Annex 8, Table 2 (for mean and SD limits of fatness, *g* and *h*) and confirm correct parameterisation of the model.	(1) Identify correct shape descriptors for model. (2) If shape descriptors were incorrect, then orientation inference was incorrect.
6	Determine number of model scenarios to run	Community to agree number of shape, and reflection coefficient permutations to run and the frequency range to examine the model over.	(1) Should the community run the model once using the mean parameters, three times using the mean and 1 SD above and below the mean, or six times using the combination of fatness and reflection coefficients? (2) Should the community work out the orientation for just the mean values of fatness and reflection coefficient or for each combination? (3) Should the community work out the frequency identification windows for just the mean values of fatness and reflection coefficients or for each combination?

(continued)

Table 1 (continued)

Step	Task	Proposed community action	Query
7	Archive SDWBA model code	Community to agree on SDWBA code to use/used and lodge version with CCAMLR.	Suggest add to FTP site.
Orientation inversion method			
8	Determine which nations currently have a method for calculating the orientation	Community to offer up appropriate code for calculating the *in situ* orientation of krill.	
9	Identify whether one orientation calculated for the whole of the Scotia Sea or per cluster area (i.e. 3)	Community to agree whether inversion process applied to the whole of the Scotia Sea or by size class clusters identified in Hewitt et al., 2004.	(1) Conti and Demer (2006) calculated both but applied only the $N(11,4)$ distribution – which do the community want to work with?
10	Identify method of inversion	Community to agree method of inversion and identification of best fit.	(1) Agree δS_v window size classes to be used (suggest 1 dB). (2) Agree method for identifying best fit (e.g. least squares best fit method).
11	Identify range of orientations (mean, SD) that inversion is to be applied over	Community to identify range of orientations that inversion is to be applied over.	(1) Should it be over all orientations?
12	Identify which acoustic data to apply the inversion process to	Community to agree which acoustic data the inversion is applied to.	(1) Demer and Conti (2005) applied inversion only to data from the RV *Yuzhmorgeologiya* – should it be Scotia Sea wide (or size class cluster wide)?
13	Identify method for correcting sample-averaging effect on orientation variance	Community to agree how correction should be applied.	SC-CAMLR-XXVIII, Annex 8, paragraph 35, noted that the inversion was carried out using measurements of S_v averaged over 50 ping and 5 m intervals. By averaging over larger areas, the variance is reduced. The Subgroup recommended that these values should be corrected to take account of this effect.
14	Archive orientation inversion method	Community to agree on inversion method and lodge code with CCAMLR.	Suggest add to FTP site.
Target identification			
15	Identify length-frequency data to calculate δS_v windows for target identification	Community to agree length-frequency range from which δS_v windows created for target identification.	(1) Community to identify what range of length-frequency data (e.g. 95 or 99%) should be used for calculating δS_v window. (2) Community to determine whether size range windows should be in 1 mm or 10 mm increments when determining δS_v window ranges.

(continued)

Table 1 (continued)

Step	Task	Proposed community action	Query
16	Identify method to create δS_v windows	Community to agree method of generating δS_v window.	(1) Is the window generated from the minimum and maximum krill sizes or the minimum and maximum dB ranges across the size range of krill sampled?
17	Determine whether two-frequency and three-frequency identification techniques should be applied to the data	Community to identify whether just three-frequency identification windows applied or whether the two-frequency window is undertaken as well.	(1) If the TS model was incorrectly parameterised, then previous two-frequency efforts may potentially have changed.
18	Apply target identification to dataset	Community to apply target identification to 50 ping by 5 m dataset.	
19	Archive identification windows	Community to lodge a set of target identification windows with CCAMLR.	Suggest add to FTP site.
Integration and latitude correction			
20	Integrate data in 1 n mile resets	Community to integrate data in 1 n mile resets (SC-CAMLR-XIX, Annex 4, Appendix G, paragraph 3.48).	
21	Apply latitude correction to data	Community to apply latitude correction to each n mile reset (SC-CAMLR-XIX, Annex 4, Appendix G, paragraph 3.51).	
22	Archive any integration code outside of Echoview and latitude correction	Community to lodge code with CCAMLR.	Suggest add to FTP site.
Create conversion factor			
23	Generate conversion factors using length/weight/TS relationships	Community to generate conversion factors.	(1) CF = $\Sigma f_i \times W(L_i)$ / $\Sigma f_i \times \sigma(L_i)$ where W = weight and L = length and f_i is frequency of the ith L class.
24	Archive associated code and a table of CF values for each modelled output	Community to lodge values and code with CCAMLR.	
Generate B_0			
25	Generate transect krill densities	Community to generate transect krill densities (SC-CAMLR-XIX, Annex 4, Appendix G).	
26	Generate B_0 estimates for each model run	Community to generate B_0 estimate for Scotia Sea according to Jolly and Hampton survey method defined in SC-CAMLR-XIX, Annex 4, Appendix G.	
27	Archive B_0 estimate/s	Community to lodge values and any associated code with CCAMLR.	

Table 2: The position vector r (including components x, y and z) and the radii values (a) delineating the generic krill shape used in the SDWBA package, and the original shape presented by McGehee et al. (1998).

	SDWBApackage20050623				Original McGehee et al. 1998			
	x	y	z	a	x	y	z	a
1	38.3500	0	0	0	41.0898	0	0	0
2	36.8563	0.9149	0	0.2147	39.4844	0.9869	0	0.2332
3	34.0464	1.7924	0	0.6525	36.4767	1.9244	0	0.6996
4	29.4160	2.4552	0	1.1296	31.5116	2.6381	0	1.2174
5	26.6247	2.4365	0	1.3537	28.5230	2.6165	0	1.4550
6	23.5253	2.4552	0	1.4470	25.2043	2.6375	0	1.5557
7	20.6967	2.3059	0	1.5964	22.1774	2.4691	0	1.7105
8	17.7000	2.2498	0	1.5497	18.9680	2.4145	0	1.6630
9	15.1888	2.0538	0	1.6524	16.2722	2.2034	0	1.7714
10	12.8456	1.8484	0	1.9044	13.7607	1.9890	0	2.0400
11	10.5304	1.6897	0	1.7551	11.2867	1.8110	0	1.8838
12	8.4672	1.6897	0	1.6524	9.0740	1.8127	0	1.7703
13	6.6468	2.0631	0	1.3816	7.1265	2.2155	0	1.4823
14	2.9687	2.4739	0	1.1016	3.1881	2.6530	0	1.1851
15	0	3.5568	0	0.5508	0	3.8150	0	0.5946

Table 3: Parameters used in the SDWBA model to estimate error in the prediction of krill TS, where number of cylinders (n_0) = 14, krill length (L_0) = 38.35 mm and phase variability (φ_0) = $\sqrt{2}/2$. Note that all parameter values, except those for orientation, are from SC-CAMLR-XXVIII, Annex 8, Table 2.

	–1 SD	Mean	+1 SD
Fatness coefficient*	1	1.4	1.7
Density contrast (g)	1.029	1.0357	1.0424
Sound-speed contrast (h)	1.0255	1.0279	1.0303
Sound speed in water (c; m s^{-1})	1461	1456	1451

* Incorrectly described as 'Radius of cylinders (r_0)' in SC-CAMLR-XXVIII, Annex 8, Table 2.

Table 4: Orientation, target identification windows, estimated B_0 and CV from simplified and full model runs using the input parameters from Table 3. LF cluster: length-frequency cluster (see paragraph 2.30); n/c: not calculated; mt: million tonnes.

Parameter	–1 SD	Mean	+1 SD
Orientation (mean,SD)	N(–17°,28°)	N(–20°,28°)	N(11°,28°)
Simplified model			
Target identification windows			
LF cluster 1 (20–40 mm)			
$\delta S_{v120\text{-}38}$	n/c	8.7 to 15.9	n/c
$\delta S_{v200\text{-}120}$	n/c	–3.5 to 2.5	n/c
LF clusters 2 and 3 (30–60 mm)			
$\delta S_{v120\text{-}38}$	n/c	–0.6 to 13.8	n/c
$\delta S_{v200\text{-}120}$	n/c	–3.5 to 2.2	n/c
B_0	n/c	87.2 mt	n/c
CV (Jolly and Hampton)	n/c	14.6 %	n/c
Full model			
Target identification windows			
LF cluster 1 (20–40 mm)			
$\delta S_{v120\text{-}38}$	12.1 to 15.1	8.7 to 14.3	5.5 to 13.8
$\delta S_{v200\text{-}120}$	–1.7 to 5.7	–5.3 to 3.9	–5.0 to 2.0
LF clusters 2 and 3 (30–60 mm)			
$\delta S_{v120\text{-}38}$	7.0 to 13.7	0.4 to 12.0	0.0 to 10.3
$\delta S_{v200\text{-}120}$	–5.5 to 2.9	–5.3 to 1.4	–5.0 to 1.3
B_0	n/c	60.3 mt	n/c
CV (Jolly and Hampton)	n/c	12.8 %	n/c

Table 5: Difference of orientation-averaged TS at two acoustic incidence angles.

Estimated orientation distribution, N(–20,28)			
	Acoustic incidence angle		
TS(dB)	90 – θ	270 + θ	Difference of TS
38 kHz	–82.6	–82.7	0.1
120 kHz	–73.8	–73.6	–0.1
200 kHz	–78.6	–78.3	–0.3

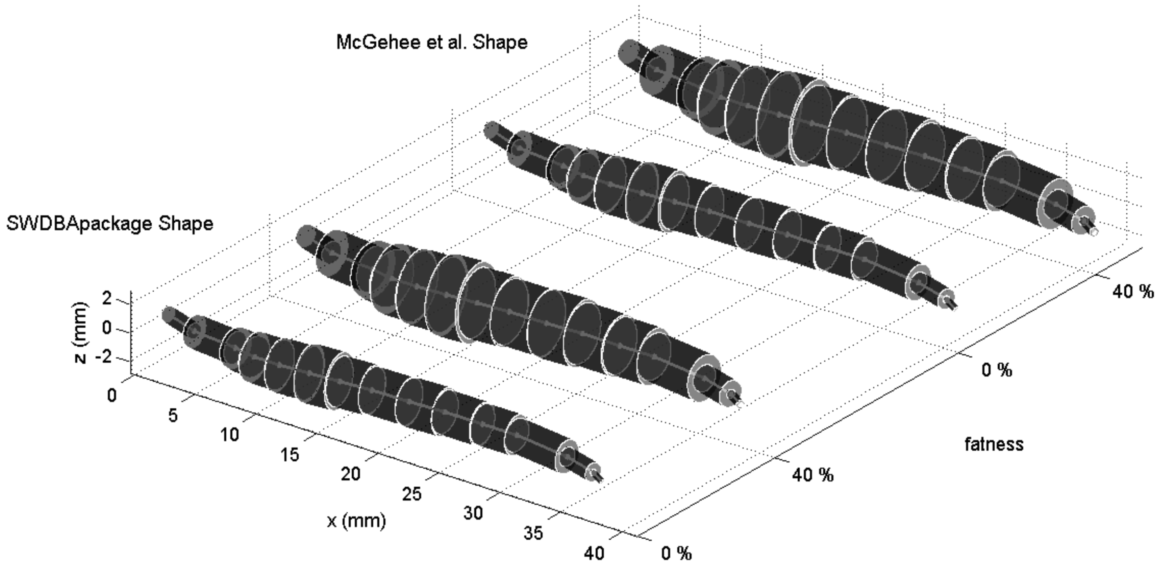

Figure 1: Illustration of the SDWBA package shape and the original McGehee et al. (1998) shape, parameterised with 0 and 40% increase in fatness, modelled to determine the SDWBA TS prediction of krill with standard AT length of 38.35 mm.

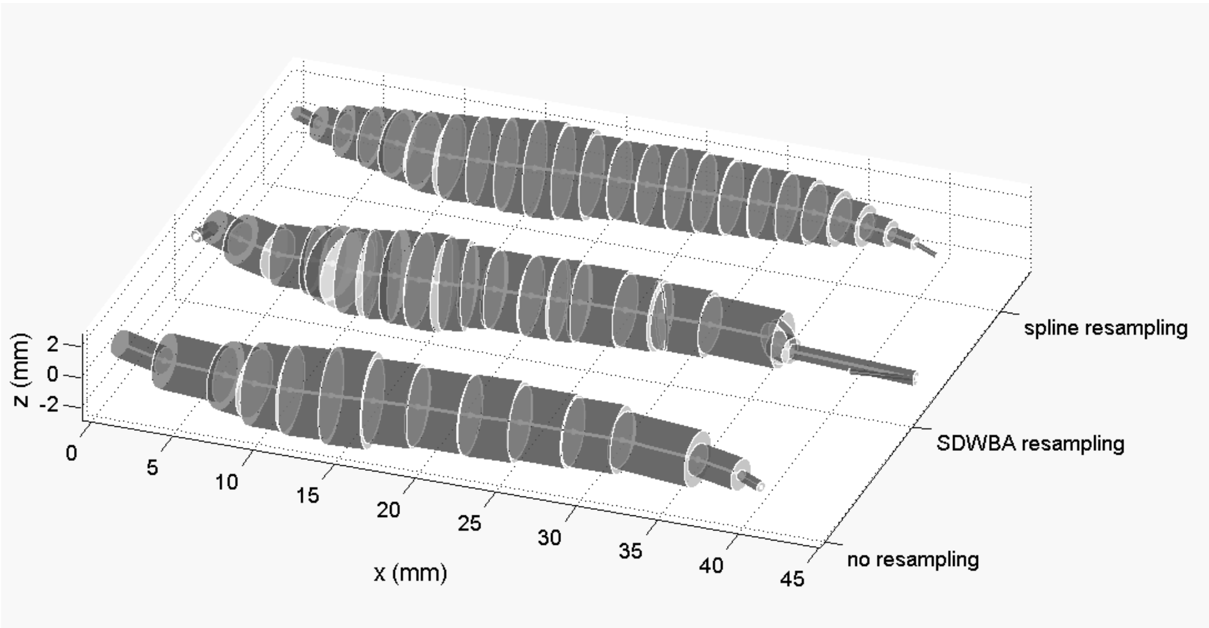

Figure 2: Illustration of the original McGehee et al. (1998) shape modelled at 200 kHz with the standard parameters without resampling process (no. cylinders = 14), resampled (no. cylinders = 24) by the SDWBA package using the Matlab resample.m function and using the simple cubic spline interpolation along the x-dimension with equidistant steps.

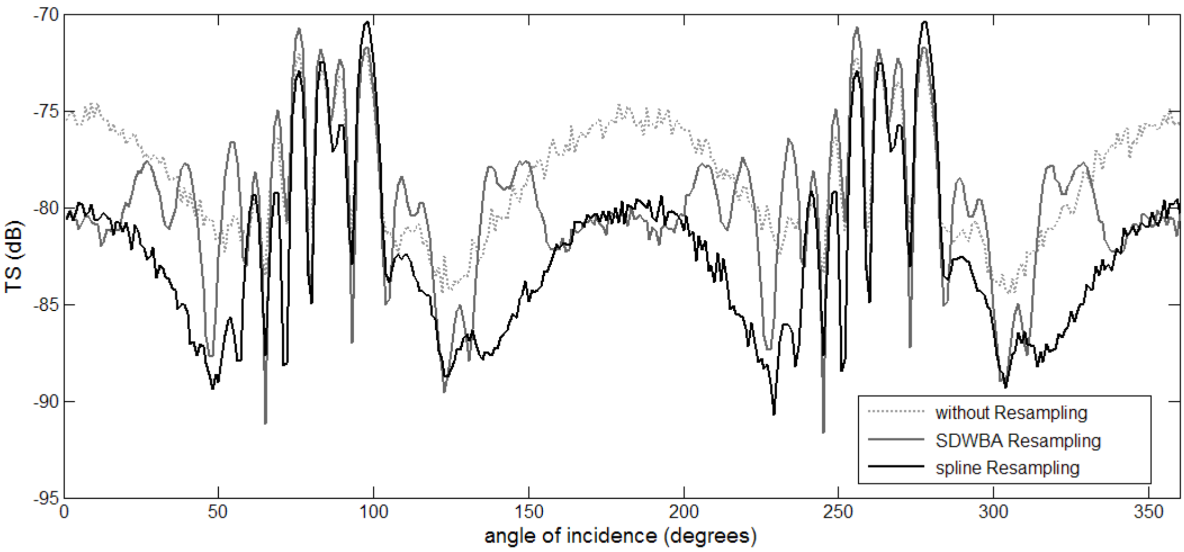

Figure 3: Predicted SDWBA TS versus angle of incidence for the original McGehee et al. (1998) modelled at 200 kHz with the standard parameters without resampling process (no. cylinders = 14), resampled (no. cylinders = 24) by the SDWBA package using the Matlab resample.m function and using the simple cubic spline interpolation along the x-dimension with equidistant steps.

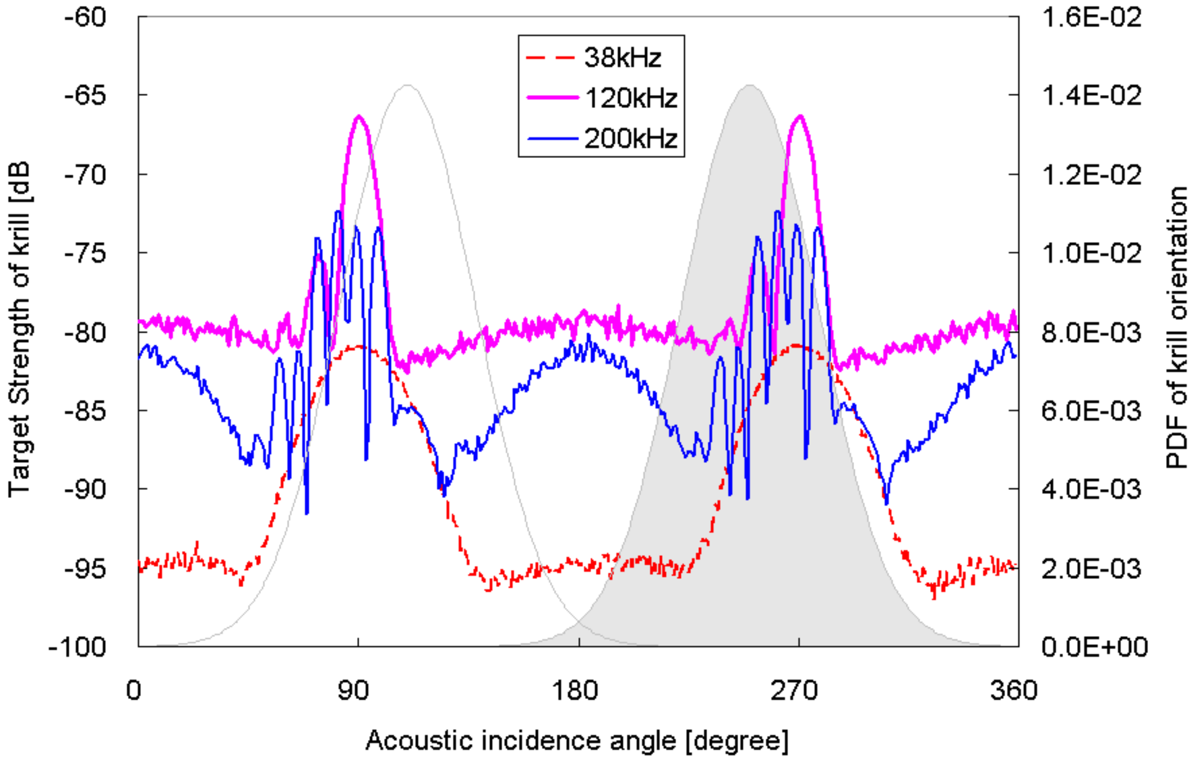

Figure 4: Estimated TS directivity and orientation of krill. Krill length is 38.5 mm.

APPENDIX A

LIST OF PARTICIPANTS

Subgroup on Acoustic Survey and Analysis Methods
(Cambridge, UK, 1 to 4 June 2010)

AGNEW, David (Dr) (Chair, Scientific Committee)	Marine Resources Assessment Group Ltd 18 Queen Street London W1J 5PN United Kingdom d.agnew@mrag.co.uk
CALISE, Lucio (Dr)	Institute of Marine Research Research Group Observation Methodology Nordnesgaten 50 PB Box 1870 Nordnes 5817 Bergen Norway lucio.calise@imr.no
COSSIO, Anthony (Mr)	Antarctic Ecosystem Research Division Southwest Fisheries Science Center National Marine Fisheries Service 3333 North Torrey Pines Court La Jolla CA 92037 USA anthony.cossio@noaa.gov
FIELDING, Sophie (Dr)	British Antarctic Survey High Cross Madingley Road Cambridge CB3 0ET United Kingdom sof@bas.ac.uk
REISS, Christian (Dr)	Antarctic Ecosystem Research Division Southwest Fisheries Science Center National Marine Fisheries Service 3333 North Torrey Pines Court La Jolla CA 92037 USA christian.reiss@noaa.gov

SKARET, Georg (Dr)	Institute of Marine Research Research Group Observation Methodology Nordnesgaten 50 PB Box 1870 Nordnes 5817 Bergen Norway georg.skaret@imr.no
TAKAO, Yoshimi (Mr)	National Research Institute of Fisheries Engineering Fisheries Research Agency 7620-7 Hasaki Kamisu Ibaraki 314-0408 Japan ytakao@affrc.go.jp
WATKINS, Jon (Dr) (Convener)	British Antarctic Survey High Cross Madingley Road Cambridge CB3 0ET United Kingdom jlwa@bas.ac.uk
WATTERS, George (Dr) (Convener, WG-EMM)	Antarctic Ecosystem Research Division Southwest Fisheries Science Center National Marine Fisheries Service 3333 North Torrey Pines Court La Jolla, CA 92037 USA george.watters@noaa.gov
ZHAO, Xianyong (Dr)	Yellow Sea Fisheries Research Institute Chinese Academy of Fishery Sciences 106 Nanjing Road Qingdao 266071 China zhaoxy@ysfri.ac.cn

Secretariat:

David RAMM (Data Manager) Keith REID (Science Officer)	CCAMLR PO Box 213 North Hobart 7002 Tasmania Australia ccamlr@ccamlr.org

APPENDIX B

TERMS OF REFERENCE

Subgroup on Acoustic Survey and Analysis Methods
(Cambridge, UK, 1 to 4 June 2010)

The Scientific Committee recommended the following terms of reference for the meeting of SG-ASAM in 2010 (SC-CAMLR-XXVIII, Annex 11):

(i) Review documentation of the acoustic protocol for the preparation of estimates of acoustic biomass.

(ii) Undertake a reanalysis of CCAMLR-2000 acoustic survey data including:

(a) confirm steps of analysis by correspondence prior to the next meeting;

(b) review the independent calculations of B_0 from the CCAMLR-2000 Survey undertaken by Members including all correspondence between Members as appropriate to clarify relevant issues;

(c) review all the documented results of (b) submitted to SG-ASAM 2010;

(d) discuss results and add clarification to protocols if necessary;

(e) agree a validated B_0 estimate and associated uncertainty from the CCAMLR-2000 Survey and submit to the 2010 meeting of WG-EMM.

(iii) Lodge a validated dataset, model code and model runs with the Secretariat.

APPENDIX C

AGENDA

Subgroup on Acoustic Survey and Analysis Methods
(Cambridge, UK, 1 to 4 June 2010)

1. Introduction
   1.1 Opening of meeting
   1.2 Meeting terms of reference and adoption of the agenda

2. Reanalysis of CCAMLR-2000 data
   2.1 Review analysis undertaken by correspondence prior to the meeting
   2.2 If necessary complete or modify analysis as appropriate
   2.3 Agree a revised estimate of B_0 and associated uncertainty

3. Documentation of the acoustic protocols
   3.1 Discuss existing documentation and add clarification where necessary arising from consideration of Agenda Item 2

4. Future work

5. Recommendations to the Scientific Committee

6. Adoption of report

7. Close of the meeting.