Annex 4

Report of the Sixth Meeting of the Subgroup on Acoustic Survey and Analysis Methods
(Bergen, Norway, 17 to 20 April 2012)

CONTENTS

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

(Bergen, Norway, 17 to 20 April 2012)

INTRODUCTION

1.1 The sixth meeting of the Subgroup on Acoustic Survey and Analysis Methods (SG-ASAM) was held at the Institute of Marine Research (IMR), Bergen, Norway, 17 to 20 April 2012. The Co-conveners, Drs R. Korneliussen (Norway) and J. Watkins (UK), welcomed the participants (Appendix A) and outlined local arrangements for the meeting and the work ahead.

1.2 The terms of reference for the meeting focused on the use of fishing-vessel-based acoustic data to provide qualitative and quantifiable information on the distribution and relative abundance of Antarctic krill (*Euphausia superba*) and other pelagic species such as myctophiids and salps (SC-CAMLR-XXX, paragraphs 2.9 and 2.10). Specifically, SG-ASAM was requested to provide advice on survey design, acoustic data collection, and acoustic data processing.

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

1.4 Documents submitted to the meeting are listed in Appendix C. While the report has few references to the contributions of individuals and co-authors, the Subgroup thanked all the authors of papers for their valuable contributions to the work presented to the meeting.

1.5 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').

THE SCIENTIFIC USE OF ACOUSTIC DATA COLLECTED ON FISHING VESSELS

Possible research objectives for fishing vessel acoustic data

2.1 The Subgroup discussed the type of research studies that could be undertaken using acoustic data collected from fishing vessels and how this could contribute to the management of the krill fishery.

2.2 The Subgroup recognised that the use of acoustic data from fishing vessels to produce an absolute krill abundance estimate that could be used as part of a stock assessment process was tractable and desirable. There was also the potential to produce indices of comparative abundance of krill that could provide a temporal context to large biomass estimation surveys or interannual scientific studies. Furthermore, there was considerable additional information that could be provided by acoustic data that could contribute to an improved understanding of the operation of the fishery.

2.3 The integration of acoustic data from fishing vessels with existing scientific surveys conducted in Subareas 48.1, 48.2 and 48.3 was essential in order to maximise the benefit to CCAMLR of those data collected on fishing vessels operating in Area 48.

2.4 The Subgroup agreed that the collection of acoustic data by fishing vessels could provide a mechanism for those that are active in the fishery but do not have the capacity to undertake scientific research surveys in the fishing areas to contribute to CCAMLR's management processes.

2.5 In order to clearly define research questions that encompass a range of operational scenarios and are achievable through the collection of acoustic data from fishing vessels, the Subgroup focused on the two following research objectives:

1. abundance of krill at a defined temporal and spatial scale, e.g. management area (or subarea) or fishing zone (referred herein as 'biomass estimation')

2. spatial organisation of krill, e.g. distribution (horizontal and vertical), swarm density or structure.

2.6 The Subgroup recognised that the survey design, equipment specifications, acoustic data quality (e.g. calibration, noise, interference) and ancillary data collection appropriate to achieve research objective 1 were likely to differ from those required to address research objective 2. The requirements for each of these objectives are given in Tables 1 and 2.

2.7 In recognising the large amount of work that has already been invested in methods for using acoustic data from fishing vessels, particularly in ICES, the Subgroup adopted the terminology introduced in the ICES report on the collection of acoustic data from fishing vessels (ICES, 2007) in respect of data collection strategies. These terms are:

- undirected monitoring – acoustic observations collected during normal fishing operations

- directed surveys – acoustic data collected following an agreed survey design

- supervised data collection – performed by a scientist on board the vessel

- unsupervised data collection – performed by the vessel's crew.

2.8 The Subgroup agreed that research objective 1 would only be achievable when undertaking directed surveys, whilst research objective 2 could be achieved using undirected monitoring as well as directed surveys. The Subgroup identified that within each of these two major research objectives there would be operational differences in the design, equipment and metadata requirements.

2.9 The Subgroup discussed how acoustic data from fishing vessels can be incorporated into an overarching ocean observing system. These data could be used to inform long-term trends (decadal) in ecosystems over basin scales and provide metrics for the development of ecological indicators. As an example the Australian integrated marine observing system (IMOS) has incorporated acoustic data from fishing vessels (www.imos.org.au/bioacoustics). This application of acoustic data was not specifically addressed at the meeting.

2.10 Whilst discussion of the collection of acoustic data during the meeting was restricted to the use of downward-looking echosounders, the Subgroup recognised that fishing vessels can also carry sonars that are capable of providing information on the three-dimensional structure of krill swarms that are not obtainable from downward-looking echosounders.

2.11 Dr M. Cox (Australia) presented a statistical technique that, with further development, may enable krill density to be estimated using data collected from fishing vessels equipped with scanning or multi-beam sonars (SG-ASAM-12/05). The Subgroup encouraged further development of the technique to address krill density estimation from directed and undirected surveys, and the analysis of avoidance using horizontal scanning sonars.

Survey design

2.12 The Subgroup noted that there were developments in stock assessment methods since the CCAMLR synoptic survey (CCAMLR-2000 Survey) that indicated that methods other than Jolly and Hampton (1990) can be used to address issues associated with the spatial distribution of krill when producing biomass estimates (e.g. Løland et al., 2007; Harbitz et al., 2009). The Subgroup encouraged continuing investigation into different survey designs for scientific and/or fishery vessels that can provide estimates of krill biomass and associated uncertainty that could be used for stock assessment.

2.13 The Subgroup agreed that an appropriate survey design would depend on the research objective (biomass estimation (1) versus spatial organisation of krill (2) above) and the equipment and sampling effort that could be allocated by the fishing vessel.

2.14 The Subgroup agreed that collecting acoustic data from fishing vessels along transects defined as part of previous/ongoing krill surveys has the potential to add significant value to the interpretation of fisheries acoustic data including to:

(i) take advantage of existing survey design and planning
(ii) compare the results of krill surveys at other times of year
(iii) provide replicate data to allow comparison of vessel noise and acoustic properties between vessels.

2.15 SG-ASAM-12/04 described how US AMLR datasets for acoustic and net data were used to simulate data that might be collected by fishing vessels to develop indices of krill biomass from a generalised linear modelling framework. Models designed for the different areas (West Shelf and Elephant Island) using single frequencies (38 or 120 kHz) produced estimates of krill biomass that were similar to those produced by the CCAMLR protocol.

2.16 The Subgroup identified four levels of survey effort that could deliver information to address one or both research objectives:

- Level 1 (directed survey) – Acoustic survey along multiple transects in a defined area with a survey effort commensurate with current scientific biomass surveys. An example of such a survey would be the five-day Norwegian collaboration (WG-EMM-11/23) occupying a former scientific survey grid around the South Orkney Islands.

- Level 2 (directed survey) – Acoustic survey along a single existing scientific transect, where vessels were unable to dedicate Level 1 effort to a survey.

- Level 3 (directed survey) – Acoustic survey of fishable aggregations, opportunistically undertaken during normal fishing operations. For example, a star- or spiral-shaped search pattern or a line transect through an acoustic target to provide information on research objective 2 (spatial organisation of krill).

- Level 4 (undirected monitoring) – Collection of acoustic data during normal fishing operations. For example, transiting to, searching for and fishing for krill in fishing grounds.

2.17 The Subgroup recognised the value of fishing vessels re-occupying transects from national research programs and noted that the fishing areas overlapped significantly with the location of these transects (Figure 1). The Subgroup recommended that the national programs lodged the waypoints from research transects with the Secretariat so that they could be distributed to the fishing vessels to encourage use of these transects.

2.18 The Subgroup agreed that in order to provide a krill biomass estimate for inclusion in a stock assessment for an area, a directed survey would need to be undertaken. This could be achieved by a single vessel undertaking multiple transects (level 1) or from multiple vessels undertaking single transects (level 2) to achieve the same level of transect coverage. Where multiple vessels were involved, an appropriate measure of uncertainty would have to include any differences in instrument performance, krill detection thresholds between vessels and other factors that are required to ensure estimates of krill biomass were comparable between vessels (ICES, 2007).

2.19 The Subgroup agreed that for biomass estimates for a given area, the expectation would be that the survey was operated with the same intensity of sampling effort commensurate with existing scientific surveys.

Acoustic data collection

Instrumentation

2.20 The Subgroup discussed the different manufacturers and frequencies of acoustic instruments currently mounted on krill fishing vessels (SG-ASAM-12/06 Rev. 1) and agreed on a set of recommendations of instrumentation requirements related to the different research objectives (Tables 1 and 2).

2.21 The Subgroup noted that the 38 kHz ES60 echosounder was used in 7 out of the 13 fishing vessels (SG-ASAM-12/06 Rev. 1) and therefore there was the potential for inter-vessel comparisons.

2.22 Based on the current methods of acoustic target identification and biomass assessment within the CCAMLR protocol, the Subgroup encouraged fitting multiple frequencies to the fishing vessels should opportunity arise. The Subgroup recommended including combinations based on 38, 70, 120 and 200 kHz.

2.23 The Subgroup agreed that calibration was a fundamental component of acoustic data collection, and that currently a standard sphere calibration (Foote et al., 1987) should be used whenever the acoustic equipment was to be used for quantitative krill biomass estimates.

2.24 The Subgroup recognised that the opportunity to undertake standard sphere calibration can be limited by, for example, location, weather conditions and availability of technical expertise. Alternative calibration methods, such as the comparison of seabed backscatter from a standard sphere-calibrated instrument and that from an uncalibrated instrument, could be appropriate for use in quantitative krill biomass estimates if the uncertainty associated with the procedures is quantified. The Subgroup strongly recommended that further research into these alternative calibration methods be carried out.

2.25 The Subgroup recognised that an ongoing assessment of system performance relative to factory settings and equipment performance expectations was a minimum requirement for usable acoustic data collection. It was recognised that comparison with non-acoustic data, such as catch data, could provide an independent validation of system performance.

Ancillary data requirements

2.26 The Subgroup discussed two levels of ancillary data requirements: fundamental and important. Fundamental ancillary data requirements are listed in Table 3. Meteorological data, such as sea state, and oceanographic data, such as temperature and salinity, were considered important but not essential.

Vessel requirements

2.27 The Subgroup recognised that vessel design and noise characteristics could have a significant effect on the quality of acoustic data collected. The Subgroup identified that examples of acoustic data from the current fishing fleet would provide a good indication of what quality of acoustic data could currently be expected.

2.28 The Subgroup recognised that interference from other acoustic instrumentation on the fishing vessels could also strongly influence data quality and recognised that attempts to minimise acoustic interference (through either turning instruments off or using synchronisation instrumentation) should be undertaken if the acoustic data are collected for a quantifiable krill biomass estimate.

Data collection protocols for krill biomass estimates

2.29 The Subgroup agreed a set of minimum requirements for the collection of acoustic data for quantifiable krill biomass estimation data:

- Survey design – directed surveys (that can be supervised or unsupervised) are required to produce quantifiable krill biomass estimates. Further research on the use of undirected monitoring surveys to estimate krill biomass and associated estimates of uncertainty is required.

- Calibration – a standard sphere calibration is required (see also paragraphs 2.23 and 2.24).

- Vessel instrument settings and metadata requirements for biomass estimation – see Table 3.

Target identification and TS estimation

2.30 The Subgroup agreed that the CCAMLR standard procedures for target identification and target strength (TS) estimation were applicable for multi-frequency surveys carried out by fishing vessels (SC-CAMLR-XXVIII, Annex 8, Appendix E). For single-frequency surveys, additional net verification of acoustic targets will be required.

2.31 The current TS model used to produce krill biomass estimates by CCAMLR is the SDWBA parameterised according to the SG-ASAM 2010 meeting. A krill length-frequency distribution representative of the krill in the surveyed area is needed to appropriately parameterise this TS model (see paragraph 2.35).

Biological sampling

2.32 The Subgroup agreed that the net used for biological sampling should be described in a manner similar to the gear specifications required in the notification to fish for krill in CCAMLR areas (CM 21-03, Annex B).

2.33 Krill length measurements should be collected according to the method described in the *Scientific Observers Manual*.

Requirements for collection of data on pelagic species other than krill

2.34 The Subgroup did not have sufficient time to consider this agenda item in detail, but it agreed that the acoustic data collection protocols recommended for krill are relevant for other pelagic species. However, target identification methods and density estimation will be dependent on the target species and require further discussion.

Collection of biological and other non-acoustic data required for acoustic interpretation and target identification

2.35 The Subgroup considered whether there was a need to collect additional samples of krill to characterise the length-frequency distribution of krill in the survey area at the time of the survey or whether the data collected according to the requirements of CM 51-06 were sufficient. The Subgroup noted that WG-EMM will consider the spatio–temporal variability in the krill size-frequency data collected by observers and requested that this analysis include an examination of an unbiased estimator of the length-frequency distribution of krill populations.

Proof of concept

2.36 In considering the terms of reference agreed by the Scientific Committee (SC-CAMLR-XXX, paragraphs 2.9 and 2.10), and in particular the request to provide a detailed list of instructions or protocols, it was not possible to provide a prescriptive set of requirements suitable for a range of vessels that might have quite different acoustic equipment and vessel noise characteristics.

2.37 Based on the description of the approach taken by the IMOS program (paragraph 2.39) to use unsupervised acoustic data collection from a range of vessels (including resupply, longline and trawl fishing vessels) the Subgroup discussed establishing a proof of concept program to work through the issues that will need to be resolved when implementing surveys from fishing vessels using different acoustic equipment. Issues that need to be addressed included whether the echo sounders on the vessels could be logged and what type of data quality was available from these instruments. Based on the data quality of the instruments it would be possible to evaluate if further data collection, surveys and post-processing should be done.

2.38 The objectives of this proof of concept would be to:

- request vessels collect digital data geo-referenced and time-referenced with associated instrument metadata suitable for evaluation of data quality
- if possible, collect acoustic data along existing transects shown in Figure 1
- take photographs of the echosounder echogram when observing a krill aggregation/target
- if possible, provide a summary geo-referenced S_v data file
- request Members to supply the Secretariat with example data from the vessels prior to the next meeting of SG-ASAM to further develop protocols.

2.39 Based on the submission of the trial datasets, future SG-ASAM meetings could develop data-screening routines that could be implemented in a consistent manner. Development of these routines could be based on filtering routines and expert data quality evaluations used in IMOS to evaluate acoustic data streams from multiple vessels.

2.40 The Simrad echosounding equipment is commonly used for both scientific research surveys and by commercial fishers, hence protocols have been developed to collect and process its digital data (ICES, 2007).

2.41 Where other echosounder devices are used in the collection of the trial datasets, the Subgroup recognised that there may be a greater overhead (e.g. in time spent developing appropriate protocols) to process the data.

RECOMMENDATIONS TO THE SCIENTIFIC COMMITTEE

3.1 The Subgroup advice to the Scientific Committee is summarised below, and the body of the report leading to these paragraphs should also be considered:

- Research objectives (paragraph 2.8)
- Levels of survey effort (paragraphs 2.17 to 2.19)
- Proof of concept (paragraphs 2.37 to 2.39).

ADOPTION OF REPORT

4.1 The report of the meeting was adopted.

CLOSE OF THE MEETING

5.1 In closing the meeting, the Co-conveners thanked the participants for their expert contributions to the development of protocols for the collection and use of acoustic data collected on board fishing vessels. They also thanked Dr R. Kloser (Australia) for his participation in the meeting as an invited expert. This collective effort, together with the generous hospitality of IMR and the excellent facilities, had fostered detailed discussions and a successful meeting.

5.2 Dr X. Zhao (China), on behalf of the Subgroup, thanked Drs Korneliussen and Watkins for co-convening the meeting and guiding the Subgroup's work.

REFERENCES

Foote, K.G., H.P. Knudsen, G. Vestnes, D.N. MacLennan and E.J. Simmonds. 1987. Calibration of acoustic instruments for fish density estimation: a practical guide. *ICES Coop. Res. Rep.*, 144: 69 pp.

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Jolly, G.M. and I. Hampton. 1990. A stratified random transect design for acoustic surveys of fish stocks. *Can. J. Fish Aquat. Sci.*, 47: 1282–1291.

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Løland, A. M. Aldrin, E. Ona, V. Hjellvik and J.C. Holst. 2007. Estimating and decomposing total uncertainty for survey-based abundance estimates of Norwegian spring-spawning herring. *ICES J. Mar. Sci*., 64: 1302–1312.

Table 1: Research objective for biomass estimation (this also includes estimates of quantitative variables such as S_v or NASC).

Objective	Calibration	Echosounder frequencies	Digital logging required	Estimate of measurement uncertainty	Comments
Quantitative biomass estimate: absolute estimate of S_v or NASC	Standard sphere[1]	≥2	Yes	Best	CCAMLR acoustic protocol uses frequencies 38, 120 and 200 kHz for target identification. 70 kHz also recommended by SG-ASAM. CCAMLR acoustic protocol recommends biomass estimation using 120 kHz. Results will be comparable between vessels and surveys. Krill length-frequency distribution required.
Quantitative biomass estimate: absolute estimate of S_v or NASC	Standard sphere[1]	1	Yes	Good (provided identification addressed)	Target identification will need to depend totally on non-acoustic methods, e.g. net-based identification. Results will be comparable between vessels and surveys depending on frequency used. Krill length-frequency distribution required.
Comparative biomass estimate	Other, e.g. bottom reference or inter-ship	≥1	Yes	Poorest	Results may be comparable with other vessels if a suitable measure of uncertainty is estimated (see paragraph 2.24). Target identification may also be compromised even with multi-frequency systems if no absolute calibration. Krill length-frequency distribution required.

[1] Standard sphere technique, Foote et al. (1987)

Table 2: Research objective for spatial organisation of krill.

Objective	Calibration method	Echosounder frequencies	Digital logging required	Estimate of measurement uncertainty	Comments
Aggregation internal density, morphological and distribution parameters	Standard sphere[1]	≥2	Yes	Best	Quantitative and qualitative aggregation parameter estimation achievable. Krill length-frequency distribution required.
Aggregation internal density, morphological and distribution parameters	Standard sphere[1]	1	Yes	Good (provided identification addressed)	Quantitative and qualitative aggregation parameter estimation achievable and requires a higher level of non-acoustic sampling than above.
Aggregation and distribution parameters	Reference to external measurement: e.g. bottom comparison, or inter-ship calibration	≥1	Yes	Poorer	Estimates will be less certain than above. A sonar is also a suitable instrument.
Aggregation and distribution parameters	Reference to factory setting only	≥1	No	Poorest	Estimates will be less certain than above. A sonar is also a suitable instrument.

[1] Standard sphere technique, Foote et al. (1987)

Table 3: Fundamental ancillary data requirements.

Type	Item	Setting	Comments
Voyage details	Start and end location; vessel name	na	
Instruments	Echosounder/sonar equipment		Manufacturer, model, serial number
	Per-instrument frequency		Single- or split-beam or sonar
Transducer specifications	Transducer depth		
	Transducer arrangement diagram		Location of transducers on hull/drop keel
	Software versions		Echosounder control software version
	Beam angle		Ideally 7° for echosounders Preferably identical for all frequencies
Settings	Power settings	25 kW m^{-2} active transducer area or less	See Korneliussen et al., 2008. Trying to avoid cavitation and non-linear loss of energy. Valid for approximately 60% transducer efficiency.
	Preferable to have identical pulse duration for all frequencies	1 ms	
	Depth settings	500 m	Maximum depth to which data is recorded and displayed, reference required
	Any noise removal settings		Periodic recording of deep data for noise characterisation (CCAMLR recommends no noise removal at data collection)
	Logging interval (ping rate)	1 to 2 s	SG-ASAM report 2010 (SC-CAMLR-XXIX, Annex 5)
	Synchronisation		Appropriate synchronisation of instrumentation is recommended to reduce acoustic interference
	Calibration details and calibration settings		E.g. gain and any correction applied to echosounder or sonar
	Absorption coefficient and speed of sound settings		Ocean water properties to estimate the absorption coefficient and sound speed may be obtained from CSIRO Atlas of Region Seas (CARS), see www.marine.csiro.au/~dunn/cars2009/
	Data format		Electronic acoustic data should be provided together with documentation of formats. The submitted data (including appropriate metadata) and data documentation must be sufficient to allow the generation of geo-referenced, depth-dependent calibrated S_v data
	GPS position		Ideally for each acoustic instrument ping and linked to instrument settings
	Instrument settings		Initial instrument settings and record of any changes to instrument settings and time when changed
	Time synchronisation		The time on all instruments should be synchronised and referenced to UTC

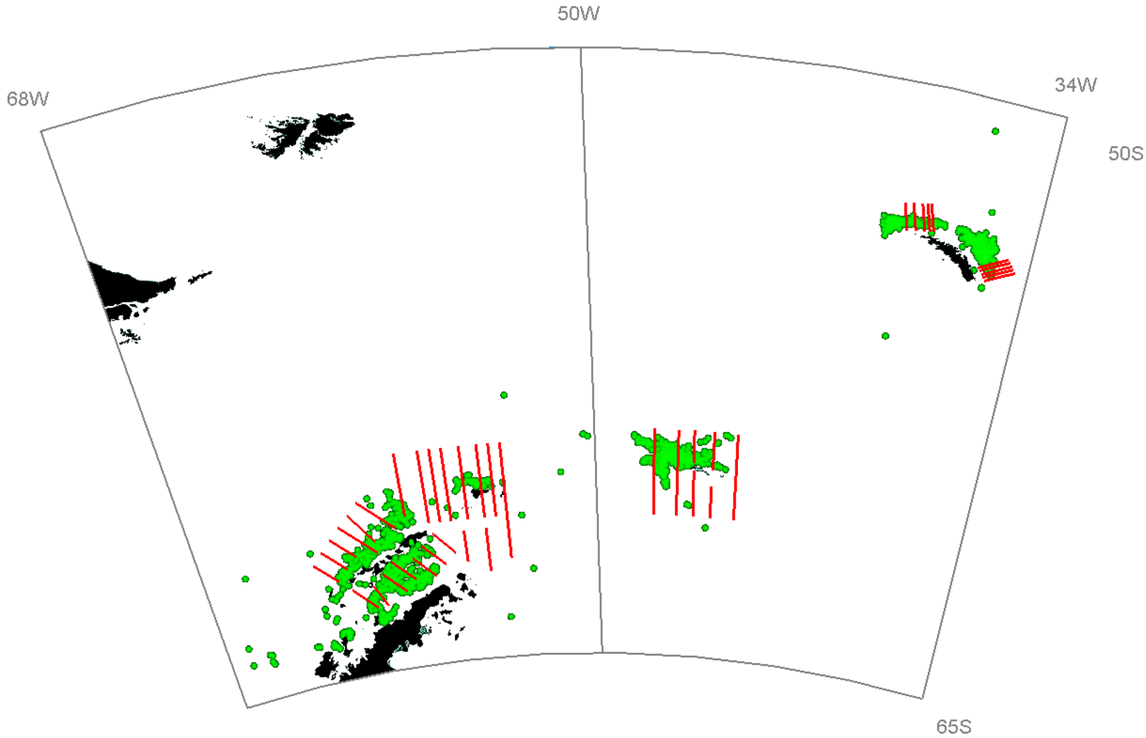

Figure 1: Location of the krill fishery in Subareas 48.1, 48.2 and 48.3 between 2009 and 2011 (green-shaded areas) and repeated acoustic transects (red lines) surveyed by Norway, the UK and the USA.

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(Bergen, Norway, 17 to 20 April 2012)

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Appendix B

AGENDA

Subgroup on Acoustic Survey and Analysis Methods
(Bergen, Norway, 17 to 20 April 2012)

1. Introduction

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

2. The scientific use of acoustic data collected on fishing vessels

    2.1 Possible objectives for fishing vessel acoustic data

    2.2 Survey design
        2.2.1 Practical survey designs for fishing vessel acoustics

    2.3 Acoustic data collection
        2.3.1 Instrumentation requirements
        2.3.2 Ancillary data requirements
        2.3.3 Vessel requirements
        2.3.4 Data collection protocols
            2.3.4.1 Minimum requirements and protocols for collection for krill data
            2.3.4.2 Requirements for collection of data on pelagic species other than krill

    2.4 Collection of biological and other non-acoustic data required for acoustic interpretation and target identification

    2.5 Acoustic data processing
        2.5.1 Calibration
        2.5.2 Target identification
        2.5.3 Biomass estimation and associated uncertainty
        2.5.4 Data management and formats

    2.6 Recommended objectives for fishing vessel acoustic data

3. Recent work on acoustics relevant to CCAMLR

    3.1 Target strength modelling
    3.2 Equipment developments

4. Recommendations to the Scientific Committee

5. Adoption of report

6. Close of meeting.

Appendix C

LIST OF DOCUMENTS

Subgroup on Acoustic Survey and Analysis Methods
(Bergen, Norway, 17 to 20 April 2012)

SG-ASAM-12/01	Draft Agenda Subgroup on Acoustic Survey and Analysis Methods (SG-ASAM)
SG-ASAM-12/02	List of participants
SG-ASAM-12/03	List of documents
SG-ASAM-12/04	Semi-empirical acoustic estimates of krill biomass derived from simulated commercial fishery data based on single-frequency acoustics A.M. Cossio, G.W. Watters, C.S. Reiss, J. Hinke and D. Kinzey (USA)
SG-ASAM-12/05	Estimating Antarctic krill density from multi-beam observations using distance sampling methods M.J. Cox (Australia)
SG-ASAM-12/06 Rev. 1	Information provided by Members on acoustic equipment on krill fishing vessels Secretariat