Annex 4

Report of the Meeting of the Subgroup
on Acoustic Survey and Analysis Methods
(Punta Arenas, Chile, 30 April to 4 May 2018)

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Report of the Subgroup on
Acoustic Survey and Analysis Methods
(Punta Arenas, Chile, 30 April to 4 May 2018)

Introduction

1.1 The 2018 meeting of the Subgroup on Acoustic Survey and Analysis Methods (SG-ASAM) was held at the Laboratorio Jorge Berguño, Chilean Antarctic Institute (Instituto Antártico Chileno – INACH), Punta Arenas, Chile, from 30 April to 4 May 2018. The Convener, Dr X. Zhao (China), welcomed the participants (Appendix A) and noted that this meeting venue was the closest to the Antarctic in which the Subgroup had ever met.

1.2 In welcoming participants to the meeting, Dr Marcelo Leppe (National Director INACH) noted the increasing awareness of Southern Ocean issues both in Chile and globally. He highlighted that the hosting of a CCAMLR meeting sent a very positive signal to the Chilean Government on the important role of INACH and Punta Arenas in Chile's engagement in CCAMLR.

1.3 The Science Manager, Dr K. Reid, thanked Dr Leppe for his kind hosting of the subgroup meeting and noted that meeting in a venue named after Ambassador Jorge Berguño Barnes, who made such a long and distinguished contribution to Antarctic affairs, exemplified the strong tradition of Chile's engagement in CCAMLR.

1.4 The meeting's provisional agenda was discussed, and the Subgroup adopted the proposed agenda without any changes (Appendix B).

1.5 Documents submitted to the meeting are listed in Appendix C. The Subgroup thanked the authors of papers and presentations for their valuable contributions to the work of the meeting.

1.6 This report was prepared by S. Fielding (United Kingdom), G. Macaulay (Norway), E. Niklitschek (Chile), K. Reid (CCAMLR Secretariat), G. Skaret (Norway) and X. Wang (China). Sections of the report dealing with advice to the Scientific Committee and other Working Groups are highlighted and collated in 'Recommendations to the Scientific Committee'.

Monitoring echosounder performance

Echosounder calibration using seabed as reference target

2.1 Mr Wang presented SG-ASAM-18/06 that described the potential to use maximum seabed backscattering to evaluate echosounder performance. Acoustic data (around 300 pings) were collected using a Simrad EK60 echosounder (38, 70 and 120 kHz) on board the Chinese krill fishing vessel *Fu Rong Hai* while drifting around a hydrographic station in the Bransfield Strait in March 2015, January 2016 and February 2018. Analysis of the 38 kHz and the 120 kHz data showed that the largest interannual variation of the mean of the maximum ping-by-ping seabed backscattering (S_v) was less than 1.0 dB, with a difference of 0.78 dB at 38 kHz and

0.35 dB at 120 kHz respectively. ANOVA analysis indicated that there was no significant difference in the distribution of maximum seabed backscattering among years at both frequencies.

2.2 The Subgroup recalled that the issue of using seabed as a reference target to evaluate echosounder performance had been investigated by SG-ASAM previously, but that the effort was mostly focused on the use of mean seabed echo integration. The Subgroup noted that the geographic location used for the three years in SG-ASAM-18/06 were not exactly the same due to the drifting nature of the vessel, and this may introduce additional uncertainty for direct comparison. The Subgroup suggested that such exercises be carried out at a calibration site in the future to enable concurrent collection of seabed signal with standard sphere calibration while maintaining the vessel in the same location.

2.3 To demonstrate the potential of this suggested approach, the Subgroup compared variation on maximum seabed S_v distribution among three consecutive years (November 2015, December 2016, January 2018) using data collected during standard sphere calibration onboard RV *James Clark Ross* in Stromness Bay. Changes to the transducer gain based on the mean value of maximum seabed S_v showed high consistency with the standard sphere calibration result at 120 kHz, but were significantly different at 38 kHz with the largest difference over 1.5 dB in 2016.

2.4 Dr Macaulay introduced an experiment by the Norwegian Institute of Marine Research (IMR) that indicated seabed integration along a fixed line can be used as an alternative calibration method to estimate transducer gain with 0.5 dB accuracy. He suggested that seabed integration was sensitive to the seabed type and bottom features and was also frequency dependent. He highlighted that it would be useful to know the bottom type along the reference stretch presented in SG-ASAM-18/06 as this might explain the variation in backscattering.

2.5 Dr K. Amakasu (Japan) drew the attention of the Subgroup to a paper (Furusawa, 2011) that described the echo integration theory for seabed echoes. The echo integration of seabed echoes is performed by setting an integration layer so as to include seabed echoes to get 'bottom Sv'. The theory is an effective tool to check the performance of scientific echosounders.

2.6 The Subgroup emphasised that the standard sphere calibration still represents the benchmark method for calibration of echosounders which had also been addressed in previous meetings (SG-ASAM 2014, 2015, 2017). However, the Subgroup continued to agree that using the seabed had substantial potential as a reference target to evaluate general performance of an echosounder, including cross-checking for different frequencies of the same echosounder. The Subgroup encouraged further development, including comparing data from the seabed at a fixed location versus transect, grid dimension in seabed integration, seabed type etc.

Internal test of echosounder performance

2.7 The Subgroup agreed that regular evaluation of the echosounder performance is an important aspect for acoustic surveys, and this is especially true if an echosounder was not calibrated using the standard sphere method. The Subgroup recalled that general functionality of a split-beam transducer can be checked by examining the single target distribution in the acoustic beam of the echosounder (SC-CAMLR-XXXIII, Annex 4, paragraph 2.26). Mr Wang presented an example of data examined using this technique and the Subgroup noted that it could be used both during a survey, and/or post-survey data analysis, to identify where an echosounder performance may have changed.

Methods for the collection and analysis of krill acoustic data from fishing vessels

3.1 In 2017, SG-ASAM agreed that there are several potential advantages of the swarm-based method compared to the dB difference method for the identification of krill when applied to data collected from fishing vessels and recommended that the swarm-based method be used when analysing acoustic data collected by fishing vessels (SC-CAMLR-XXXVI, Annex 4, paragraphs 3.2 and 3.3). The Subgroup recalled that the swarm-based method:

(i) is not dependent on data from a specific set of acoustic frequencies which is required when setting the dB difference window for krill identification following the CCAMLR protocol

(ii) reduces the risk of integrating noise-contaminated segments of the data

(iii) provides potentially interesting information about swarm dynamics and swarm characteristics which would not be available from standard interval integration

(iv) potentially reduces data processing time.

3.2 The Subgroup recognised that some misunderstanding had arisen because of the terminology used by different authors to describe different components of the analytical process, specifically, the terms gridded or interval method inherited from SG-ASAM-17/02. The Subgroup clarified that the distinction between the two methods that have been recommended by SG-ASAM was in the target identification method used to discriminate between krill and other targets, such that:

(i) the swarm-based target identification approach that uses the Shoal Analysis and Patch Estimation System (SHAPES) algorithm, parameterised according to SC-CAMLR-XXXVI, Annex 4, Table 1, to identify 'krill' targets in acoustic data

(ii) the dB-window target identification method using two or more frequencies subtracted from each other, parameterised by a knowledge of the krill length frequency and an acoustic scattering model or empirical measurements (e.g. Madureira et al., 1993).

3.3 The Subgroup agreed that the distinction between the target identification methods provided a useful means for distinguishing the swarm-based and dB-window-based approaches as used in the papers submitted to, and in the report of, the Subgroup. However, a more comprehensive review and clarification of the terminologies is needed to reflect the development of acoustic techniques considered by SG-ASAM.

3.4 The Subgroup noted that although the Echoview template agreed at SG-ASAM-17 (SC-CAMLR-XXXVI, Annex 4, Appendix D, available from https://github.com/AustralianAntarcticDivision/EchoviewR/tree/master/inst/extdata) has the potential to apply 'dB differencing' for 120 kHz – 38 kHz, the default settings of a –20 to 20 dB difference range is so wide as to be functionally equivalent to not using a dB-window to identify krill. The dB difference option is retained in the template to enable future research to be carried out on the sensitivity of swarm-based approaches to krill length-frequency data.

3.5 SG-ASAM-18/04 provided a comparison of the swarm-based and dB-window target identification methods using uncalibrated acoustic data collected by the Chinese fishing vessel *Furong Hai* over four years from 2013 to 2017. Interval echo-integration units of 250 m × 1 n mile were used to sum the nautical area scattering coefficient (NASC) attributed to krill for both identification methods. High correlation was observed between the two techniques (Pearson correlation $r > 0.9$) across all years. Similar cumulative distribution patterns were observed (over the range of observed NASC values), and there were no significant differences between distributions of NASC values identified using the two identification techniques. Overall, the paper showed good agreement between the swarm-based identification method and the dB-window target identification method.

3.6 The Subgroup welcomed the comparison of a swarm-based approach applied to fishery vessel data and thanked Dr X. Yu (China) who undertook further analyses during the meeting and presented these in SG-ASAM-18/04 Rev. 1. The Subgroup noted that:

(i) differences between methods within a year were lower than the interannual variability

(ii) the distributions of normalised differences in NASC values between the two methods were symmetrically distributed around zero

(iii) data were highly correlated and linearly related and the regression line for three of the four years had a slope of ~1

(iv) the slope of the regression in 2016 was 1.27 and the cumulative NASC values calculated along transects indicated that this difference between the two methods arises from a small number of strong swarm targets.

3.7 Based on the analysis presented in SG-ASAM-18/04 Rev. 1, the Subgroup agreed that this reinforces the agreement from SG-ASAM-17 that the swarm-based approach is a suitable technique to investigate variability in krill density and/or distribution.

3.8 The Subgroup agreed that further analysis to improve the comparison between methodologies should include:

(i) conducting a detailed scrutiny of the data and echograms from 2016 in order to identify issues causing observed discrepancies and allow for some additional learning about the comparative performance of both methodologies

(ii) using a geometric regression rather than a predictive regression since both methods estimate krill density with error

(iii) pairwise comparison of means, along with, or instead of, Kruskal-Wallis comparison of distributions

(iv) applying an identification dB-window to swarm-based analysis, as in SG-ASAM-17/02, to evaluate the potential inclusion of other schooling organisms prevalent in some of the Antarctic (e.g. lanternfish (*Electrona carlsbergi*), mackerel icefish (*Champsocephalus gunnari*) and Antarctic silverfish (*Pleuragramma antarctica*)) (see paragraph 3.4)

(v) echo-integration by region (swarms) was suggested for further consideration as it would produce biologically meaningful information (swarm density) and should not affect transect-based (Jolly and Hampton, 1990) abundance estimates.

3.9 SG-ASAM-18/01 examined the efficacy of different frequencies used with a two- and three-frequency dB window identification method to identify Antarctic krill (*Euphausia superba*) (e.g. Madureira et al., 1993), whilst determining krill density always using the 120 kHz. Data from three surveys were used and different dB windows were applied to each survey based on length-frequency data from RMT8 nets. A Bland Altman analysis was used to show that only a combination of 120 and 70 kHz data ($S_{v120\text{-}70}$) shows agreement (low bias) compared to the dB window using 120 and 38 kHz, and likewise only a combination of 200, 120 and 70 kHz is comparable to the dB window using 200, 120 and 38 kHz.

3.10 The Subgroup noted that choosing frequency pairings with similar scattering (e.g. Rayleigh or Geometric) appeared to have poorer identification performance compared with pairs chosen from each scattering type and noted that the results presented in SG-ASAM-18/01 indicated that the transition from Geometric to Rayleigh scattering occurred somewhere between 70 and 120 kHz for the size range of Antarctic krill. The Subgroup noted that there was strong agreement between methods, except those using the 70–38 kHz dB window at the 500 m integration bin scale, but identified that mean values for each transect within each survey showed a poorer agreement during cruise JR15002 than the other two surveys and occasionally some large discrepancies between techniques. It was noted that the size range of krill was considerably different during JR15002 compared with the other two cruises.

3.11 The Subgroup considered how changes in the distribution of krill length frequencies, krill material properties and orientation could influence the krill identification windows both between surveys and within a survey. This included trying different dB windows, not based on in situ krill length frequencies, to compare efficacies of different 'sized' zooplankton windows as well as using simulated data to aid the understanding of complex interactions that involve decisions on the use of different dB windows, krill length-frequency distributions as well as krill material properties.

3.12 The Subgroup noted that despite comparable results at a 500 m integration bin level for the 120 kHz–70 kHz frequency combination, compared with 120 kHz–38 kHz, there was sufficient discrepancy at the transect level to warrant further investigation into the causes. The Subgroup noted that further work is required before accepting that the krill density estimates made using different frequency pairs between vessels or surveys were comparable.

Analysis of data collected from fishing vessels

4.1 SG-ASAM-18/08 provided an analysis of the density and biomass of krill around the South Shetland Islands conducted on the krill fishing vessels *Kwang Ja Ho* in April 2016 and *Sejong* in March 2017. This paper included density and biomass estimates using the dB window method and the swarm-based procedure developed at SG-ASAM-17 (SC-CAMLR-XXXVI, Annex 4, paragraph 2.6). For the survey in 2016 the mean density of krill was 7.34 g m^{-2} using the dB window method and 13.99 g m^{-2} using the swarm-based method.

4.2 The Subgroup noted that in SG-ASAM-17/04 the mean density of krill in the survey in April 2016 was 13.37 g m^{-2} using the dB window method. However, in SG-ASAM-18/08 the mean density from the same survey was 7.34 g m^{-2} using the dB window method. The Subgroup agreed that it was essential to understand the reason for this change in the value of density from the same survey before evaluating the comparison of the results from the dB window method and the swarm-based method for the same survey.

4.3 Following discussion of potential analytical issues, the authors of SG-ASAM-18/08 welcomed the offer from Dr M. Cox (Australia) to assist with a reanalysis of the data the using the dB window method and the swarm-based method.

Survey methods

2019 Krill Synoptic Survey of Area 48

5.1 SG-ASAM-18/07 outlined the proposal for a Norwegian-led Krill Synoptic Survey of Area 48, comprising a multinational acoustic trawl survey with confirmed contributions from both research and fishing vessels. The proposed survey design closely follows the CCAMLR 2000 Krill Synoptic Survey of Area 48. The proposal included the formation of a Survey Coordination Group to further plan the survey, data processing and data management. Advice was requested from SG-ASAM on the contents of a survey operation manual, a plan for processing workflow, including priority outputs, a timeline for delivery of results and suggestions for the use of existing CCAMLR data protocols and data management tools.

5.2 The Subgroup welcomed the formation of a Survey Coordination Group led by Norway, and recommended that the Survey Coordination Group conduct a pre-survey meeting to facilitate vessel coordination, procedure standardisation and coordination of survey activities, including a plan for carrying out the analysis of the survey data, along with a timeline of expected analysis products. The Subgroup also encouraged the Survey Coordination Group to use the existing CCAMLR e-group for the Area 48 krill survey 2019 (https://groups.ccamlr.org/mnrg2016) for planning and coordination of the survey.

5.3 The Subgroup recommended that the Survey Coordination Group should contain at least one person from each Member participating in the survey.

Acoustic activities

5.4 Dr Skaret presented the acoustic data collection protocol for the 2019 large-scale survey that was developed during the SG-ASAM meeting (Appendix D). This protocol prescribes, in detail, the acoustic configuration and data collection procedures, and was endorsed by the Subgroup as appropriate for ensuring the collection of usable acoustic survey data.

5.5 The Subgroup recommended that all participating survey vessels have a suitable echosounder that operates at 38 kHz and 120 kHz.

5.6 The Subgroup recommended that a minimum acoustic performance be specified for vessels to participate in the survey and welcomed the offer from IMR to request the required passive or active acoustic data from each vessel (see Appendix D) and carry out this assessment prior to the survey. The Subgroup recommended that a noise level that allows the detection of targets of -76 dB at 250 m is an appropriate minimum acceptable level. The Subgroup also recommended that the analysis of candidate vessels be made available for discussion at WG-EMM-18.

5.7 The Subgroup noted that the noise level analysis could also be used to optimise the survey speed of the vessels so as to collect high-quality acoustic data, or the survey design could be modified to minimise the effect of this on the survey data.

5.8 The Subgroup recommended that an acoustician be on board all vessels, to ensure that the survey procedures are followed and data of sufficient quality are collected.

5.9 The Subgroup noted that other forms of echosounder performance checks, such as inter-calibration between vessels and seabed calibration methods (see paragraphs 2.1 to 2.7) are desirable.

5.10 The Subgroup noted that during the CCAMLR-2000 Survey acoustic transects were only conducted during daylight hours. Dr Macaulay stated that the current intention is to conduct acoustic surveying both during the day and at night.

Sampling activities

5.11 The Subgroup emphasised the importance of specifying standardised krill measurement protocols for use in acoustic biomass estimation and that this should be based on the CCAMLR-2000 Survey RMT 8 protocol. The Subgroup noted that although the nets proposed for use in the survey differed between vessels, this was unlikely to significantly bias the resultant krill length distributions.

Other items

5.12 The Subgroup recommended that the Survey Coordination Group prepare a survey manual for presentation at WG-EMM. The manual should include acoustic procedures (Appendix D), survey design, analysis procedures and contingencies for different levels of available vessel effort. Attention should be given to the fact that the distribution of the fishery has changed since 2000 and that the survey coverage could be changed to cover where the fishery occurs today. The Subgroup noted the potential for inclusion of the US AMLR transects (including in Bransfield Strait) in the 2019 survey.

5.13 The Subgroup recommended the development of contingency plans that could include how to adjust to unexpected loss or delay of vessel and/or survey time. Consideration should be given to whether delayed survey effort is better redirected to repeating already completed transects. In the case of reduced survey effort, consideration should be given to redirecting effort to transects in the areas of krill fishery operation such as the US AMLR transects in Subarea 48.1 and the Norwegian survey transects in Subarea 48.2.

5.14 The Subgroup also noted the following items for consideration in planning the survey:

(i) the survey design would only be 'synoptic' if all the vessels participated at the same time. The Subgroup recalled that the CCAMLR-2000 Survey was undertaken within a one-month period (mid-January to mid-February) and the vessels operated simultaneously

(ii) the benefit of carrying out the initial processing and analysis of the data on a vessel-specific basis so that potential vessel bias can be identified and isolated

(iii) the vessels participating in the survey should be allocated transects to complete, rather than a fixed number of days of survey effort

(iv) the survey should include oceanographic observations from all survey areas

(v) data management would need to be given further consideration by the Survey Coordination Group and that this consideration should include the Secretariat and the Data Management Group.

5.15 SG-ASAM-18/09 provided a description of the acoustic data collection on the South African research vessel, SA *Agulhas II*, which has been proposed as a vessel that will contribute to the 2019 survey. The Subgroup agreed that the echograms in SG-ASAM-18/09 indicated that the 38 and 120 kHz echosounders on that vessel would meet the minimum acoustic performance criteria for acoustic surveys of Antarctic krill (see paragraph 5.6).

Japanese krill survey

5.16 SG-ASAM-18/03 described a revised outline of the dedicated krill survey in Division 58.4.1, planned for the 2018/19 season. The Subgroup noted that the plans included operation of an ADCP (Ocean Surveyor (OS) 38 kHz, RD Instruments) at 38 kHz and an echosounder for depth sounding (ES60 12 kHz, Simrad), with the potential for interference with the 38 kHz survey echosounder. Dr K. Abe (Japan) reported that he conducted an experiment in the western North Pacific in January 2018 to investigate whether such an interference could be avoided by using the K-sync synchronisation system and he found that it could be avoided with appropriate settings. In the experiment, the bottom detecting function of an EK80 was turned off (assuming that the Japanese Antarctic survey would mainly be conducted in deep water). No interference was observed in the water column from 0 to 500 m if the transmission interval of the EK80 was forced to 2 seconds while the transmission interval of the OS38 and ES60 was forced to 4 seconds. Although OS38 pings were observed at depth ranges greater than 700 m in the echograms of EK80 38 and 70 kHz, it would not affect the krill biomass estimation because only data from 0 to 500 m are used for the estimation. Nevertheless, Dr Abe cautioned that a seabed artefact due to the self-echo (double reflection of bottom) of the EK80 38 kHz appeared on the echogram when the bottom depth was around 1 500 m if the transmission cycle of the EK80 was forced to 2 seconds. In such cases, it would be necessary to change the transmission cycle in the field to accommodate the problem.

5.17 SG-ASAM-18/02 contained more detailed information on the dedicated krill survey in Division 58.4.1, planned for the 2018/19 season. This included information on planned supporting and analysis activities, including measurement of krill density and sound speed contrast, plans for collection of broadband data (see details under Item 6), and the use of the CCAMLR-2000 Survey protocol for data analysis

Other business

Broadband acoustics

6.1 SG-ASAM-18/05 outlined a proposal to investigate the utility of broadband signals for Antarctic krill acoustic surveys during the krill survey in Division 58.4.1 during 2018/19 on the Japanese research vessel *Kaiyo-maru*. Echo sampling by a Simrad EK80 echosounder in frequency modulation (FM) mode (broadband pulses) will be simultaneously performed during targeted RMT1+8 tows. Spectra of volume backscattering strengths will be calculated from the sampled echoes and their characteristics will be investigated in order to improve current krill identification methods. Also, the potential for the acoustic inference of orientation and length distributions of in situ krill will be investigated using the measured spectra and theoretical acoustic scattering models.

6.2 In response to a question about the possibility of collecting broadband acoustic data to infer orientation during krill surveys, Dr Amakasu noted that each broadband channel must be pinged sequentially to avoid cross-channel interference, so the acoustically sampled volumes are inappropriately different among four broadband channels at survey speeds. Furthermore, as there was a requirement to use single-frequency signals during the transects during the survey described in SG-ASAM-18/02, broadband data collection would only be performed during targeted RMT1+8 tows.

6.3 The Subgroup recognised the importance of the work on orientation inference from broadband data given the role of the orientation angle distribution of krill in biomass estimation and looked forward to receiving the results of the investigation at a future meeting.

6.4 Dr Macaulay provided an update on developments in the use of broadband acoustics in fisheries research from the ICES Working Group on Fisheries Acoustics Science and Technology (WGFAST) held in March 2018. This included details of the papers presented and a notification of the ICES training course on 'Principles and Methods of Broadband/Wideband Technologies: Application to fisheries acoustics' to be held in 2019. Of particular note to SG-ASAM was ongoing work to reconcile differences observed during inter-comparison measurements of single frequency data from EK60 and EK80 echosounders.

6.5 The Subgroup thanked Dr Macaulay and agreed that it was important to keep abreast of developments in this area noting that broadband acoustics, while it would be unlikely to be used during acoustic biomass surveys, is likely to provide important ancillary information to improve the interpretation of the identification and biomass conversion parameters used in those surveys.

Autonomous acoustic data collection

6.6 The Subgroup noted a proposal from Norwegian scientists to deploy autonomous acoustics data collection 'Sailbuoys' in conjunction with the research from the Norwegian vessel *Kronprins Haakon* in 2019. These devices are equipped with an EK-80 echosounder (333 kHz) and an acoustic modem for communication with moored instrumentation.

6.7 The Subgroup noted the potential advantages of the development of such autonomous data collection systems and looked forward to seeing the results from the first deployment in the Antarctic region.

Analysis of acoustic data from fishing vessels during un-designed surveys

6.8 The Subgroup noted a research proposal from Mr J. Canseco (Chile) to evaluate biomass estimates from non-designed surveys. The aim of the study is to compare density estimates using acoustic data of krill from krill fishing vessels during routine fishing operations with spatially contemporaneous estimates from the proposed large-scale survey in 2019. In order to do so there was a need to access raw acoustic data from those vessels fishing for krill during the period of the large-scale survey.

6.9 The Subgroup encouraged the development of collaborations between Chilean scientists, including acousticians and scientific observers, working on Chilean krill fishing vessels in the development of this project.

6.10 The Subgroup noted that the notifications of intention to fish for krill (Conservation Measure (CM) 21-03) includes information on which vessels are proposing to fish for krill and also details of the echosounder equipment on board those vessels and that this would provide a means to identify potential collaborators.

Advice to the Scientific Committee and Future Work

7.1 The Subgroup noted that progress had been made on some of the important elements of future work identified by SG-ASAM-17 (SC-CAMLR-XXXVI, Annex 4, paragraphs 6.1 and 6.7), including the comparison of the swarm-based approach with the dB window method, nonetheless all of those future work topics identified by SG-ASAM-17 remained relevant to the work of the Subgroup.

7.2 Areas of additional future work identified by the Subgroup in this meeting include:

(i) review and clarification of the terminologies is needed to reflect the development of acoustic techniques considered by SG-ASAM (paragraph 3.3)

(ii) specific analysis to improve the comparison between swarm-based and dB window methodologies (paragraph 3.8)

(iii) reanalysis of data from Korean surveys the using the dB difference window and the swarm-based method (paragraph 4.3).

7.3 The Subgroup suggested that a joint survey analysis workshop be held for the Norwegian-led and Japanese surveys that will be conducted in 2019 to ensure consistency in acoustic analysis procedures and result production. The Subgroup encouraged the participants of the krill surveys in Division 58.4.1 and Area 48 to collaborate more broadly and look for opportunities to combine data and make comparative studies of these two contrasting areas.

7.4 The Subgroup noted the proposal for a joint workshop between SG-ASAM, WG-EMM, WG-SAM on Acoustic survey methods and design to facilitate feedback management (FBM) in 2019 (SC-CAMLR-XXXVI/BG/40) according to the priorities of the Scientific Committee. Noting the proposed workshop to analyse acoustic survey data from Norwegian and Japanese surveys conducted in 2019, the Subgroup requested the Scientific Committee consider whether this would be instead of or in addition to the regular meeting of SG-ASAM.

7.5 The Subgroup noted that if the proposed workshop to analyse acoustic survey data was held prior to the joint workshop between SG-ASAM, WG-EMM, WG-SAM then the presentation of the preliminary results from these surveys could make an important contribution to the consideration of the acoustic survey methods and design to facilitate FBM.

Remote participation

7.6 Dr Fielding expressed her thanks to the Subgroup for facilitating her remote participation in the meeting via Skype, although she acknowledged that it was not the same as actually being in the meeting.

7.7 The Subgroup noted that this had been very successful in the case of one person joining the meeting remotely but identified that additional facilities would need to be considered if remote participation in working group meetings was to the rolled out more broadly.

Adoption of the report

8.1 The report of the meeting was adopted.

Close of the meeting

9.1 At the close of the meeting Dr Zhao thanked all participants for their productive and positive contributions to the work of SG-ASAM. Dr Zhao also thanked Dr Cardenas and his team at INACH for creating such a warm atmosphere for the meeting. He also thanked the Secretariat for their efficient support to the meeting.

9.2 Dr Zhao also thanked Dr Fielding for her remote contribution to the meeting especially given differences in time zones and looked forward to her participation in person at future meetings.

9.3 On behalf of the Subgroup Dr Reid thanked Dr Zhao for his guidance, patience and technical expertise in convening the meeting recognising that this had ensured the effective engagement of all participants.

References

Furusawa, M. 2011. Echo integration near the seabed. *J. Mar. Sci. Tech.–Japan*, 19 (3): 259–266.

Jolly, G.M. and I. Hampton. 1990. A stratified random transect design for acoustic surveys of fish stocks. *Can. J. Fish. Aquat. Sci*., 47 (7): 1282–1291.

Madureira, L.S.P., P. Ward and A. Atkinson. 1993. Differences in backscattering strength determined at 120 and 38 kHz for three species of Antarctic macroplankton. *Mar. Ecol. Prog. Ser*., 93 (1–2): 17–24.

Appendix A

List of Participants

Subgroup on Acoustic Survey and Analysis Methods
(Punta Arenas, Chile, 30 April to 4 May 2018)

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Appendix B

Agenda

Subgroup on Acoustic Survey and Analysis Methods
(Punta Arenas, Chile, 30 April to 4 May 2018)

1. Opening of the meeting
2. Calibration of echosounders
3. Methods for the collection and analysis of krill acoustic data from fishing vessels
4. Analysis of data collected from fishing vessels
5. Survey methods
6. Other business
7. Advice to the Scientific Committee
8. Adoption of the report and close of the meeting.

Appendix C

List of Documents

Subgroup on Acoustic Survey and Analysis Methods
(Punta Arenas, Chile, 30 April to 4 May 2018)

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SG-ASAM-18/02	An outline of narrowband echosounder survey methods to estimate biomass of Antarctic krill in CCAMLR Division 58.4.1 during 2018/19 season by the Japanese survey vessel, *Kaiyo-maru* K. Abe, K. Amakasu, R. Matsukura, T. Mukai and H. Murase
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Appendix D

The 2019 large scale krill survey of Area 48

Acoustic sampling protocols

1. The following protocols are set for the purpose of standardising acoustic data collection and archival from multiple ships during the multinational effort to synoptically survey the entirety of Area 48 during the austral summer of 2018/19. Methods for data analysis are not considered here, rather the primary objective of these protocols is to make the data collections as comprehensive and uniform as possible across all research platforms. Whenever possible, exact equipment, software and settings have been specified. In the cases where exact matches are not possible, pertinent comparative information has been specified.

Echosounder

2. The following echosounder models are acceptable to use:

(i) Simrad EK60, software version ER60 2.4.3

(ii) Simrad EK80, software version EK80 1.12.1 (a more recent version will be available before the survey and this will most likely be recommended)

(iii) EK80/ES80 software be used to control the GPT instead, as this avoids the triangle wave error present in ES70 data. However, it is acknowledged that moving to EK80/ES80 software requires a more powerful computer to run the software and that this may not be feasible.

Transducers

3. Preferred transducer models have 7° conical beamwidths that allow approximately equivalent insonified volumes.

38 kHz: Simrad split-beam (e.g. ES38-7, ES38B)
70 kHz: Simrad split-beam (ES70-7C)
120 kHz: Simrad split-beam (e.g. ES120-7, ES120-7C)
200 kHz: Simrad split-beam (e.g. ES200-7, ES200-7C).

4. Single-beam transducers at the same frequencies are acceptable if there is at least one split-beam transducer co-located with the single-beam transducer to allow for efficient calibration of the single-beam transducer.

5. Transducers with beamwidths other than 7° may be acceptable. However, using a standard 7° conical beam width would ensure approximately equivalent insonified volumes. This will be advantageous for employing multi-frequency methods for swarm delineation.

6. Mounting configuration should be documented by scaled technical diagrams, suitable for positioning them on both the alongship and athwartships axes. Record should be made of blister, or trunk dimensions and location on hull; acoustic window material and acoustic properties; and the transducer depths, dimensions and relative locations.

7. The transducers should be mounted as close to each other as possible.

Settings

8. Echosounder settings files should be agreed upon and used by all survey participants for the survey, calibration and noise measurement operations; only settings determined by individual system calibrations might differ (e.g. gain, Sa correction, beam angles, transducer depth).

9. Before the initial calibration experiments, critical system-specific settings should be updated following Table 2 in this appendix and specifications and should not be changed. Compliance with the prescribed settings should be checked daily.

10. Particularly notable settings:

(i) For EK80/ES80: use single-frequency pulses (CW not FM).

(ii) For EK80/ES80 the pulse slope must be set to ‘Fast’.

(iii) A pulse repetition rate of 2.0 seconds will be used for survey and noise measurements. Faster rates (0.5 seconds) should be appropriate for calibration.

(iv) Pulse durations of 1.024 ms will be transmitted at all three frequencies.

(v) The transducer depths will be set to the nominal mounting depths for each transducer.

(vi) A mean sound speed and mean absorption coefficient will be provided; all echosounders will be set using these values. Note a CTD prior to calibration will be used to set these values during calibration, but the mean values should be used for the survey and noise measurements.

(vii) Data for each ping and frequency will be recorded at 0–1 100 m for EK60 and ES70 and for EK80/ES80 within the following ranges:

(a) 38 kHz: 0–1100 m
(b) 70 kHz: 0–1100 m
(c) 120 kHz: 0–500 m
(d) 200 kHz: 0–300 m.

(viii) Echosounder time should be reset to correspond with logging PC/GPS time at the start of each day’s survey at a minimum – or synchronised to the ship’s GPS network clock using appropriate software.

(ix) Echosounder computer time must be within 5 seconds of the GPS time.

(x) Time must be entered in UTC, which needs to be used as the only time for all logging and sampling procedures aboard. The use of UTC should be cross-checked among the acoustic, biological and oceanographic components of the cruise.

(xi) The log menu/distance will be set only once to 0.0 n miles at the end of the initial calibration.

Data logging

(i) Data must be logged continuously in .raw format into dedicated hard drives.

(ii) A daily backup must be carried out (e.g. on to a second external hard drive or network server).

(iii) Data discs can be provided by IMR, on request.

System calibration: standard sphere calibrations

(i) Ideally, system calibrations will be performed at all frequencies immediately before and after the survey in appropriate locations. However, a single calibration at appropriate sites within the study area in the survey period is required. Suitable locations should be free from strong freshwater input. Good examples of suitable locations within the study area include Rosita Harbour and Stromness Bay, South Georgia; Scotia Bay, South Orkney; and Admiralty Bay, King George Island.

(ii) Sphere calibration must follow ICES CRR 326 standard procedures (Demer et al., 2015). Some particular issues to be highlighted:

(a) if at all possible, the transducer faces must be cleaned of debris and bio-fouling prior to the initial calibration

(b) during the entirety of both pre- and post-survey calibration experiments, all acoustic data will be logged in .raw files

(c) record must be made of the calibration: date; time; location; sea state (swell, wind, currents, ice); water temperature profile; salinity profile; sound speed profile; bottom depth; calibration apparatus; and ship’s mooring configuration

(d) the 38.1 mm WC sphere must be used as the standard target. If possible, spheres will be purchased from a single production batch and provided to all parties by the Norwegian Institute of Marine Research (IMR)

(e) a calibration rig can be borrowed from another nation or the Association of Responsible Krill harvesting companies (ARK)

(f) theoretical TS = f (bandwidth and sound speed) will be provided (Table 1) for the EK60 and ES70. For the EK80, the sphere material properties are entered into the EK80 calibration program

(g) the calibration parameters should be estimated using the echosounder software of either the ER60 (for EK60 and ES60) or the EK80 (for ES70 and EK80)

(h) it is recommended to update calibration parameters before running the survey.

System check

11. Echosounder operation checks must be carried out daily. These checks are to include:

(i) examination of the spatial distribution of single target detections to check for abnormal distributions

(ii) for the ES80/EK80, use of the BITE view to monitor the transducer impedance

(iii) inspection of the background noise level as reported by the echosounder software.

12. If feasible, the use of the seabed echo amplitude as an echosounder operation check is encouraged.

Pre-cruise characterisation of system noise

13. A pre-cruise background noise characterisation is required before the cruise in order to establish a baseline noise level and identify the speed at which appropriate quality data is collected. In order to do this, data are required to be collected in passive or active mode, using prescribed settings (Table 2) in water depth greater than 50 m (in passive mode) or greater than 300 m (in active mode). Data collected should cover a range of speeds. Ideally, 15 minutes per 6 knots, 7 knots, 8 knots, 9 knots, 10 knots, 11 knots and 12 knots.

Survey operations

14. Whenever possible, survey at a constant speed of 10 knots (or as instructed from pre-cruise characterisation of system noise – see above); acoustic noise perceived by each of the echosounder frequencies will be routinely monitored and speed adjusted if needed to reduce noise or increasing speed to maintain schedule as needed (provided noise level is acceptable).

Necessary preliminary investigations

15. Bench test echosounder using chosen settings and logging options.

Metadata logging

16. Metadata must be logged according to ICES (2016), trawl metadata will be recorded as part of the trawl station work and catch recording. Logging of environmental data should follow Table 3. Acoustic metadata is automatically recorded by the echosounders.

17. A survey log must be kept. This log must include these items:

(i) start and stop times and positions of transects

(ii) times and positions of other survey activities (e.g. trawls, oceanographic stations, calibrations)

(iii) other items of note that are relevant to the survey, such as diversion of vessel from transects, reasons for doing so, equipment problems, etc.

References

Demer, D.A. 2004. An estimate of error for the CCAMLR 2000 survey estimate of krill biomass. *Deep-Sea Res. II*, 51: 1237–1251.

Demer, D.A., L. Berger, M. Bernasconi, E. Bethke, K.M. Boswell, D. Chu, R. Domokos, A.J. Dunford, S. Fässler, S. Gauthier, L.T. Hufnagle, J.M. Jech, N. Bouffant, A. Lebourges-Dhaussy, X. Lurton, G.J. Macaulay, Y. Perrot, T. Ryan, S. Parker-Stetter, S. Stienessen, T. Weber and N. Williamson. 2015. Calibration of acoustic instruments. *ICES Coop. Res. Rep.*, 326: 1363 pp.

ICES. 2016. A metadata convention for processed acoustic data from active acoustic systems. Version 1.10. *Series of ICES Survey Protocols, SISP 4-TG-AcMeta*: 48 pp.

Observing Handbook No. 1 (2010). National Weather Service. Marine Surface Weather Observations. May 2010. US Department of Commerce.

Table 1: Calibration sphere target strength values
Sphere diameter = 38.1 mm
Sphere density = 14900 kg m^{-3}
Sphere compressional sound speed = 6864 m s^{-1}
Sphere shear sound speed = 4161.2 m s^{-1}
Water density = 1025.3288 kg m^{-3}
Pulse duration = 1.024 ms

Sound speed (m/s)	Sphere TS at 38 kHz	Sphere TS at 70 kHz	Sphere TS at 120 kHz	Sphere TS at 200 kHz
1450	–42.01	–40.56	–39.84	–39.44
1455	–42.06	–40.65	–39.76	–39.48
1460	–42.11	–40.74	–39.69	–39.50
1465	–42.16	–40.83	–39.63	–39.50
1470	–42.20	–40.92	–39.58	–39.48
1475	–42.23	–41.01	–39.54	–39.44
1480	–42.26	–41.09	–39.52	–39.38
1485	–42.29	–41.18	–39.5	–39.30
1490	–42.31	–41.25	–39.51	–39.22
1495	–42.32	–41.33	–39.52	–39.13
1500	–42.33	–41.39	–39.55	–39.04
1505	–42.33	–41.45	–39.59	–38.96
1510	–42.33	–41.50	–39.63	–38.90
1515	–42.33	–41.54	–39.69	–38.85
1520	–42.32	–41.57	–39.76	–38.81

Table 2: Echosounder settings

Parameter	Value	Comment
Pulse duration	1.024 ms	
Transmit power	38 kHz: 2 000 W 70 kHz: 750 W 120 kHz: 250 W 200 kHz: 150 W	The selectable values differ slightly between the EK60/ES70 and EK80/ES80. Choose the closest value that is equal to or less than the given values.
Pulse slope	Fast	Only applicable to ES80/EK80 systems.
Ping interval	2.0 s	
Vessel speed	8–10 knots	Subject to sufficiently low noise levels.
Sound speed	1 456 m s^{-1}	Obtained from Table 1 of Demer (2004), derived from Scotia Sea measurements.
Absorption coefficient	38 kHz: 10.4 dB km^{-1} 70 kHz: 18.9 dB km^{-1} 120 kHz: 27.7 dB km^{-1} 200 kHz: 41.3 dB km^{-1}	Obtained from Table 1 of Demer (2004), derived from Scotia Sea measurements. 70 kHz value derived from weighted harmonic mean temperature and salinity values from the same table.
Data recording depth	38 kHz: 1 100 m 70 kHz: 1 100 m 120 kHz: 500 m 200 kHz: 300 m	For EK60/ES70 systems use 1 100 m for all frequencies.
Pulse type	CW	Only applicable to ES80/EK80 systems.

Table 3: Environmental data to be recorded

These are to be collected four times daily (00:00, 06:00, 12:00, 18:00 UTC) as per the WMO Voluntary Observing Ships Scheme, following guidelines provided in the US National Weather Service Observing Handbook No. 1 (2010).

Wind speed	
Wind direction	
Sea state	
Ice conditions	
Ice cover	
Cloud cover	
Air temperature	
Dew point	