Annex 4

Report of the Working Group on Acoustic Survey and Analysis Methods 2023 (WG-ASAM-2023)
(Tokyo, Japan, 22 to 26 May 2023)

Contents

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(Tokyo, Japan, 22 to 26 May 2023)

Introduction

1.1 The 2023 meeting of the Working Group on Acoustic Survey and Analysis Methods (WG-ASAM) was held at the Tokyo University of Marine Science and Technology from 22 to 26 May 2023 in Tokyo, Japan.

Opening of the meeting

1.2 The Convener, Dr X. Wang (China), welcomed the participants (Appendix A), noting that the Co-convener, Dr S. Fielding (UK), was unable to participate in this meeting. The Convener noted that this was the first in-person meeting of the group as a working group, and that it was a pleasure to have an in-person meeting because it had online meetings in 2020, 2021 and 2022 due to the COVID pandemic and had previously been a subgroup.

Adoption of the agenda

1.3 The meeting's provisional agenda was discussed and the Working Group adopted the agenda (Appendix B).

1.4 Documents submitted to the meeting are listed in Appendix C. The Working Group thanked the authors of papers and presentations for their valuable contributions to the work of the meeting. Acronyms used in this report are provided on the website.

1.5 This report was prepared by M. Cox (Australia), D. De Pooter (Secretariat), T. Dornan (UK), S. Menze (Norway), T. Okuda (Japan), S. Parker (Secretariat) and G. Zhu (China). Sections of the report detailing advice to the Scientific Committee and other working groups are highlighted in grey and summarised under 'Advice to the Scientific Committee'.

Review of the terms of reference and workplan

2.1 The Working Group reviewed the terms of reference agreed by SC-CAMLR-41, noting the inclusion of climate change in its advice. The Working Group noted that while a focus of WG-ASAM is to develop methods, it could include consideration of the impact of climate and environmental change, where relevant, in its advice. It also noted that acoustic data may be used to monitor and document other ecological aspects of the effects of environmental change.

2.2 The Working Group reviewed the workplan it developed in 2022, noting that the short-term tasks were included in its agenda for the 2023 meeting. The Working Group noted that krill length-frequency sampling is necessary for both catch length distribution and for length distribution data for converting acoustic backscatter data into biomass estimates. The Working Group noted that both of these sampling goals could be met by standardised length distribution sampling and provided advice to the 2023 Workshop on Krill Fishery Organisation (WS-KFO-2023) to align the length-frequency sampling with other observer tasking (paragraphs 4.16 to 4.19).

Standardised procedures for acoustic surveys and development of krill biomass estimates

3.1 WG-ASAM-2023/07 highlighted that because krill swarms may extend deeper than 250 m, the application of a depth integration limit of 250 m potentially misses biomass. However, data quality on 120 kHz could be insufficient to collect data deeper than 250 m, and at times was of too poor quality because of acoustic noise to be useable on some surveys. The paper also noted some discrepancies between the 120 kHz and 38 kHz biomass estimates that need further exploration. Noting that krill length-frequency has a large influence on biomass estimates, the authors suggested that additional work was needed to use variable length-frequency distributions in calculating biomass estimates.

3.2 The Working Group recalled that integrating data from deeper than 250 m may become problematic with use of 200 kHz using the 3-frequency dB differencing method. The Working Group noted that analyses could report both integration to 250 m and the maximum reliable depth of the dataset. The Working Group also noted that a constant depth of surface exclusion layer at 20 m will ignore biomass in the upper layer, and encouraged the development of autonomous methodologies that may be able to distinguish krill within this surface layer.

3.3 The Working Group recalled that the potential use of 70 kHz for krill identification and biomass estimates had been discussed before (SG-ASAM-2017, paragraphs 2.16 and 6.1). The Working Group also noted that krill are relatively weak acoustic targets and smaller krill may be undersampled at lower frequencies. The Working Group agreed that further research into the use of 38 and 70 kHz was required to test their validity in estimating krill biomass.

3.4 The Working Group noted that biology and seasonal depth distributions can influence krill detection and target strength (TS) estimation. Krill may move deeper to benthic habitats in autumn and winter, potentially out of the effective detection range of echosounders or the lower depth integration limit. Also, female krill in late summer are in spawning condition and are high in lipids, which may affect their acoustic properties.

3.5 The Working Group encouraged further investigation into the effect of the seasonal changes of krill biology and vertical distribution on its biomass estimates.

3.6 WG-ASAM-2023/01 presented an updated method for defining and calculating spatial polygons that could be dynamically updated as coastlines were updated, proposed thresholds for line densification and a standardised projection using the European Petroleum Survey Group (EPSG) code 6932.

3.7 The Working Group welcomed this standardised methodology and requested that both the spatial objects and the R code used to generate them (including the version of the coastline data) be made available via the CCAMLR GitHub repository.

3.8 The Working Group agreed that the defined protocol be used when planning surveys, as stratum areas will affect biomass estimates.

3.9 The Working Group endorsed the recommendations that:

(i) geographical information system (GIS) objects use the EPSG 6932 projection

(ii) lines of more than 0.1 degree of longitude be densified

(iii) polygon vertices be given clockwise in decimal degrees with at least five decimal places

(iv) vertices be added where polygons meet

(v) inland vertices be used for polygons that are bound by the coastline

(vi) areas be clipped to all coastlines (continent and islands) based on the most recent available coastline data, and that the bearing from the last vertex to the intersection with a coastline should be specified in the polygon definition

(vii) analyses cite CCAMLR geospatial data (i.e. shapefiles) as CCAMLR. [*Year*]. Geographical data layer: [*Layer name*]. Version [*Version*], URL: [*URL*].

3.10 WG-ASAM-2023/P02 presented a method of estimating Antarctic krill biomass on a weighted per-length basis using length to wet mass observations and krill length data from combined routine and target trawl data. Stage-based uncertainty of biomass estimates was difficult to estimate because of significant overlap in length-frequency distribution among juvenile, male and female krill.

3.11 The Working Group noted that a single length-to-weight relationship was applied to estimate biomass but that during summer spawning female krill bodies may be larger than males at the same length. However, without more detail on the ratios of krill developmental stages in the population, a single length-weight relationship was currently an adequate approach. It was also noted that time and resource pressures at sea were likely to limit the ability to collect the amount of data that stage-specific length-weight relationships would require.

3.12 The Working Group noted that to capture the overall krill size distribution, a combination of data from target and regular trawls was appropriate.

3.13 The Working Group noted that the Institute of Marine Research (IMR) in Norway's 'StoX' biomass estimation package for fish implements a per-length biomass for fish. However, the target strength (TS) to length relationship for fish is normally represented by a simple log-log regression while the krill TS to length relationship is nonlinear in log-log space so requires more parameters. The Working Group agreed that developing the StoX software to include functionality for a krill length-weight relationship to progress a standardised acoustic biomass estimation method for krill would be useful. Dr Menze offered to work with IMR to progress incorporating stochastic distorted-wave Born approximation (SDWBA) for krill into the StoX program.

Storage of acoustic data

3.14 WG-ASAM-2023/09 presented recent developments on the CCAMLR Acoustic Data Repository and highlighted the data submitted since the previous WG-ASAM meeting. The paper noted that the significant difficulties with low upload speeds experienced by Members while submitting these data could be addressed by moving towards a cloud-based exchange server. The paper also presented a newly developed data exploration tool and proposed modifications to the 'Instruction manual for the collection of fishing vessel-based acoustic data' as requested by WG-ASAM in 2022.

3.15 The Working Group thanked the Secretariat for the development of the Acoustic Data Repository and Members for submitting the data. The Working Group supported the proposal for the Secretariat to investigate a cloud-based solution for exchanging acoustic data. The Secretariat noted that the estimated total cost of the repository based on current data exchange volumes (A$1 500) will increase by at least one order of magnitude when accounting for the potential expansion of the fishery, expansion in data collected by the software and a potential increase in collection effort.

3.16 The Working Group noted that a standardised procedure for naming files would be useful in addition to the parameters that can be used to filter data using the acoustic data explorer tool. The Working Group also identified that criteria defining the completion of an adequate transect need to be developed.

3.17 The Working Group noted that krill length data are typically only collected by observers during fishing rather than acoustic transects. The Working Group recalled that both research and fishery trawls can catch representative length distributions and that length samples could be collected by observers during sampling trawls conducted during a nominated acoustic transect (SG-ASAM-2019, paragraph 2.37).

3.18 The Working Group welcomed the development of the acoustic data explorer tool and recommended that it be made available to Members though the Members-only section of the CCAMLR website.

Collection and analysis of acoustic data on board fishing vessels

Methods for calibrating echosounders on fishing vessels

4.1 On behalf of the authors, Dr Cox presented WG-ASAM-2023/05, which provided information on the calibration history between 2009 and 2023 of three New Zealand toothfish fishing vessels.

4.2 The Working Group expressed its gratitude for this useful summary of calibration and data collection. Noting that some calibration parameters (WG-ASAM-2023/05, Table 2) changed by a large magnitude between years the Working Group recommended that future calibrations present additional information, including water temperature at calibration site and the root mean square (RMS) error of the calibration results and whether the echosounder equipment had been upgraded, to help interpret these changes.

4.3 The Working Group also recommended that for ES80 and EK80 systems, regular monitoring of the impedance be carried out, for example, by recording the impedance whenever the vessel leaves port.

4.4 The Working Group also noted that in earlier years, echosounder settings (pulse duration and power) between calibrations were different than in recent years. It further noted that because calibration parameters are specific to these settings, changing settings between calibrations makes detecting any trend in calibration values difficult. However, the Working Group recognised that the calibration settings in WG-ASAM-2023/05 had not changed since 2015.

4.5 WG-ASAM-2023/08 presented the results of seafloor calibrations conducted over the last 10 years at two locations close to the Southern Orkney Islands by Norwegian vessels. The method was carried out at two sites with one transect per site as calibration reference targets. From the two sites, the deeper site 2 had longer term stability (WG-ASAM-2023/08, Figure 6).

4.6 The Working Group agreed with the study recommendation that near-concurrent completion of transects by a sphere-calibrated vessel and an uncalibrated vessel would improve the results of the calibration. The Working Group suggested that seabed substrate data could be collected at the two study sites (e.g. from multibeam information on both topography and backscatter) and used to help identify new suitable sites.

Survey design and data collection for fishing vessels

4.7 WG-ASAM-2023/02 presented a Python package (Krillscan) that automates the analysis of backscatter data. The analysis is carried out automatically on board vessels with the processed data being transmitted back to shore, currently using email.

4.8 The Working Group noted, through a motivating example, the enormous variation in the presented krill biomass time-series data at the South Orkney Islands. The snapshot vessel-based acoustic surveys may not sample the krill distribution sufficiently to represent the 'true' krill biomass. The Working Group recognised that autonomous data collection and analysis approaches will help to address this but will generate vastly bigger datasets. The Working Group noted that automated processing approaches will be essential to accommodate bigger datasets delivered from fishing vessels and autonomous platforms.

4.9 The Working Group commended Dr Menze for his work on the open-source automated processing software (the Krillscan Python module version 0.2.21). It noted that this software can be used on a variety of operating systems and is freely available on GitHub (github.com/sebastianmenze/krillscan; accessed: 23 May 2023).

4.10 The Working Group noted that there is a constant difference between Krillscan and large-scale survey system (LSSS) methods (WG-ASAM-2023/02, Figure 5). This difference is likely due to be the internal noise removal methods of the LSSS and the difference is subject to ongoing investigation.

4.11 The Working Group recommended that the Secretariat work with Dr Menze to test the Krillscan package using krill fishing vessel acoustic data collected along nominated transects.

4.12 To facilitate testing, the Working Group suggested it develop test datasets, as recommended in WG-ASAM-2022, paragraph 2.13, to benchmark processing software and methods.

4.13 The Working Group thanked the Secretariat for the proposed modifications to the 'Instruction manual for the collection of fishing vessel-based acoustic data' (Appendix D) and made additional updates in response to the additional sampling capacities of broadband echosounders (i.e. Simrad EK80 and ES80).

4.14 To keep the collected data volume within manageable transfer and processing limits, the Working Group agreed that data should continue to be collected in continuous wave (CW) mode and not frequency-modulated (FM) mode. Also, the Working Group agreed that data should be collected in 'Power/Angle samples' mode for ES80 and EK80 units. It also requested that file names of raw data should include a unique vessel identifier (e.g. International Maritime Organization (IMO) number) and the instrument type (e.g. EK80) as a prefix. The Working Group also revised the maximum raw file size to 100 MB.

4.15 The Working Group recommended that the updated instruction manual (Appendix D) be made available to fishing vessels and be available on the CCAMLR website.

Krill biological data collection

4.16 The Working Group considered the collection of krill length-frequency data to support the acoustic data collected by fishing vessels on nominated acoustic transects. The Working Group recognised that krill length data are a vital component for acoustic-based krill biomass estimation. Additionally, morphological data, for example, sex, maturity stages and weight (wet mass), are also useful because they may also influence TS as well as ecological studies.

4.17 The Working Group agreed that both oblique and target trawl methods can be used to collect krill samples during a nominated transect survey. For the nominated transects, both commercial and scientific nets can be used, with a preference to use scientific nets. In line with WG-EMM-18/23, all krill should be measured in samples with fewer than 150 individuals. For larger krill catches, a minimum of 150 krill should be measured and stage determined.

4.18 The Working Group suggested that other biological information (i.e. catch composition) should be collected for other species, for example, numerical sample size should be collected for the purposes of validating the composition of acoustic targets.

4.19 The Working Group encouraged the development and validation of new krill length-frequency sampling technologies (e.g. stereo cameras).

Krill biomass estimates

Area 48 biomass estimates

5.1 The Working Group recalled WG-EMM-2021/05 Rev. 1 which presented results from the 'Krill biomass estimates from acoustic surveys' intersessional e-group. The Working Group discussed the workflow used to calculate biomass estimates for each of the management strata as they are defined by WG-ASAM-23/01 (Appendix E).

5.2 The Working Group thanked Dr Dornan for creating the workflow document during the meeting, the updates to the krill biomass estimates in strata of Subarea 48.1 (Table 1), and the R code to calculate the revised estimates.

5.3 The Working Group suggested that the Secretariat make the metadata table, the R code and the workflow document available together to Members through a private section of the CCAMLR GitHub repository where updated versions can be maintained as additional survey data become available.

5.4 The Working Group noted that small deviations from biomass estimates compared with earlier calculations (WG-ASAM-2022, Table 9), and that deviations are attributed to the updated areal definitions of the management strata and to rounding of values in 2022.

5.5 WG-ASAM-2023/06 described the change in krill biomass and density at the start, middle and end (May, July and September respectively) of the 2022 fishing season at South Georgia. Diel patterns in biomass were detected, with significantly higher biomass being detected at night in July and September.

5.6 The Working Group welcomed this contribution and noted that the RMT1 net (610 µm mesh size, 1 m^2 mouth area) used in the survey may be more likely to catch smaller krill than the RMT8, which typically has a larger mesh size. The Working Group noted that net avoidance by larger krill may have occurred due to the small mouth area and encouraged the authors to compare their krill length-frequency data with those collected by the krill fishery operating in the area.

5.7 The Working Group discussed sampling of swarms deeper than 200 m, noting that the sensitivity analyses in WG-ASAM-2023/06 suggested that excluding krill at depths between 200 and 250 m had minor impact on the krill biomass estimates. However, even a 250 m depth threshold would not detect deeper swarms.

Area 58 biomass estimates

5.8 WG-ASAM-2023/10 provided corrections to the mean weighted areal krill biomass density and the degree of coverage values provided in Table 2 of WG-ASAM-2021/06. The authors noted that these were transcription errors and that the biomass estimate reported in WG-ASAM-2021/06 remains unchanged.

5.9 The Working Group thanked the authors for providing the corrections.

5.10 WG-ASAM-2023/P01 presented the result of an acoustic trawl survey carried out in February and March 2021 to estimate the krill biomass in the eastern sector of Division 58.4.2 (biomass = 6.48 million tonnes, areal biomass density = 8.3 g m^{-2}, coefficient of variation (CV) = 28.9%), based on daytime data in line with the CCAMLR 2000 Krill Synoptic Survey of Area 48, and assessed the efficacy of extrapolating smaller surveys to a wider area at a similar latitude.

5.11 The Working Group welcomed the study and noted that the heterogenous spatial distribution of krill density and length-frequency in the area might complicate upscaling the biomass estimates from several random small box areas to a wider area. The Working Group noted that a time series of small box area surveys may be useful to examine seasonal biomass trends within the box, but many small areas would be needed to capture spatial patterns in abundance in a wider area.

5.12 The Working Group noted that at night krill are detected shallower in the water column and potentially occur in the top 20 m, which may not be fully assessed using hull-mounted acoustic detection methods (paragraph 3.2). The Working Group noted that biomass estimate studies could be augmented using mooring-based echosounders (paragraph 6.2) which may be able to assess the region closer to the surface.

5.13 The Working Group requested that Members specify the method used to categorise day and night sampling and noted the nautical twilight calculator on the CCAMLR website (www.ccamlr.org/node/84096).

5.14 WG-ASAM-2023/P03 presented a study which used broadband acoustic data and length-frequency distribution data obtained from trawl samples to predict the length-averaged TS spectra of krill. The study found that the model worked well for krill aggregations dominated by krill smaller than 35 mm, but detected discrepancies for aggregations dominated by larger krill.

5.15 The Working Group welcomed the contribution and noted that the discrepancies observed were likely caused by differences in the orientation parameters used by the model, and encouraged Members to further investigate krill orientation distribution.

5.16 The Working Group recalled its recommendation that the results of acoustic krill biomass surveys presented to CCAMLR be accompanied with standardised metadata describing the data collection, including metadata tables (WG-ASAM-2022, paragraphs 2.13, 2.15 and Tables 2 to 8), and encouraged Members to include this information in future submissions.

Survey design using other platforms

6.1 WG-ASAM-2023/04 presented the deployment and results from moored 120 kHz EK80 echosounder data in Subarea 48.3 (South Georgia) between 13 January 2018 and 1 February 2022. These data indicate considerable seasonal and interannual variability in the presence, size and shape of krill swarms, and the diurnal variability of krill abundance, highlighting more acoustic backscatter during winter at night, which conventional daytime-only surveys would miss.

6.2 The Working Group welcomed the challenging study to increase opportunities for monitoring krill abundance and behaviour in the Southern Ocean. The Working Group noted that moored echosounders are a relatively cost-effective tool for the collection of long-term krill data with the capacity to measure temporal variability at high resolution.

6.3 The Working Group noted that similar projects exist in the surrounding areas, and noted the increasing value of autonomous systems for krill study and the potential to use autonomous vehicles and systems to elucidate not only temporal variation but also spatial variation.

Development of methods to estimate biomass of finfish using acoustic techniques

7.1 WG-ASAM-2023/03 presented an overview of a mackerel icefish (*Champsocephalus gunnari*) survey conducted with the *More Sodruzhestva* in February 2022 in Subarea 48.2, consisting of eight transects west of the South Orkney Islands. Acoustic data were gathered with an ES80 echosounder at 120 kHz and are currently being held securely by the UK. Catch data were gathered at 37 trawl stations, along with net-mounted conductivity temperature depth probe (CTD), camera and flowmeter data for each haul.

7.2 The Working Group noted that the echosounder was last calibrated in 2018, before the 2019 Area 48 Survey. The vessel plans to install a 38 kHz transceiver (provided by Australia) and calibrate the echosounder before the next survey. The Working Group encouraged possible cooperation and support with on-site calibration if the *More Sodruzhestva* was at the South Orkney Islands at the same time as other vessels.

7.3 The Working Group noted that relevant metadata should be collected and presented considering the CCAMLR protocols presented in tables in WG-ASAM-2022.

7.4 The Working Group supported the idea of a Ukrainian scientist to apply for a CCAMLR scholarship to analyse these survey data and the UK indicated it could provide mentors in support of this. Dr L. Pshenichnov (Ukraine) thanked participants for their assistance and equipment donations.

Future work

8.1 The Working Group agreed additions to the WG-ASAM workplan in Table 9 of SC-CAMLR-41 (see Table 2), to include that:

(i) the parameter values in the SDWBA model of TS (i.e. orientation and fatness, *g* and *h* values) be improved through a better understanding of the influence of krill length distribution and seasonal and regional effects of developmental stage on target strength

(ii) investigations be conducted on the effects of uncertainty in length distributions on biomass estimation

(iii) methods be developed to use acoustics to monitor biological change to the pelagic ecosystem and how this is communicated to the CCAMLR Ecosystem Monitoring Program (CEMP).

Advice to the Scientific Committee

9.1 The Working Group identified the following items relevant to providing advice to the Scientific Committee to inform its future work:

(i) standardised methodology for defining spatial objects (paragraph 3.9)

(ii) endorsed updates to the instruction manual for fishing vessel acoustic data collection (paragraph 4.15)

(iii) updates to the WG-ASAM workplan (paragraph 8.1).

Adoption of report and close of meeting

10.1 The report of the meeting was adopted.

10.2 At the close of the meeting, Dr Wang thanked all participants for their efficient work and collaborative data analysis that had contributed greatly to the successful outcomes from the meeting. In particular, he thanked the Japan Fisheries Research and Education Agency and the Tokyo University of Marine Science and Technology for hosting the meeting, the North Pacific Fisheries Commission for administrative support, all the coordination work performed by Dr Okuda and Dr H. Murase (Japan), support from the Secretariat, and the student volunteers who made the meeting function smoothly.

10.3 Dr Parker thanked Dr Wang for his leadership and technical guidance throughout the work of his first in-person meeting as Convener.

10.4 Dr Wang thanked all the meeting participants for their support during the meeting.

Table 1: Updated krill biomass estimates in strata of Subarea 48.1 using the strata areas provided in WG-ASAM-2023/01 for all available years 1996–2020. These values update the biomass estimates compared with those generated in 2022 even where stratum area did not change due to the use of rounded values in 2022. The R code and metadata used to generate the values is available upon request from the Secretariat GitHub. The workflow used to generate these values is described in Appendix D.

Stratum	Density ($g\ m^{-2}$)	Variance of weighted density	CV of weighted density (%)	Stratum area based on WG-ASAM-2023/01	Biomass (tonnes)	CV of biomass (%)	Number of surveys
Joinville (JI)	37.42	410.24	46.86	23 001	860 729	49.52	11
Elephant (EI)	65.49	487.64	26.69	51 648	3 382 317	26.92	27
Bransfield (BS)	34.19	343.83	41.28	35 180	1 202 654	42.83	30
South Shetland Islands West (SSIW)	53.45	326.48	32.86	47 118	2 518 544	36.26	29
Gerlache Strait (GS)[2]	58.53	1 364.44	63.11	44 616	839 494[3]	63.11	1
Powell Basin (PB)[1]	32.73	155.75	38.13	144 375	2 295 219[3]	38.13	1
Drake Passage (DP)[1]	41.53	40.53	15.33	294 079	9 059 380[3]	15.33	1

[1] Single survey: 2019 Area 48 Survey (WG-ASAM-2019).
[2] Single survey: 2020 *Atlantida* survey (WG-ASAM-2021/04 Rev. 1).
[3] Note that these values were the lower one-sided 95% confidence interval of the biomass estimates due to only having a single survey.

Table 2: Annotated table of WG-ASAM research priorities updated for 2023. CEMP – CCAMLR Ecosystem Monitoring Program, DSAG – Data Services Advisory Group, SISO – Scheme of International Scientific Observation.

Theme	Topic/task	Timeframe	Contributors	Secretariat participation
1. Target Species	(a) Develop methods to estimate biomass for krill			
	(i) Survey design standards for regional and synoptic surveys	Short/Medium	ASAM members	
	(ii) Develop methods to use fishing fleets as monitoring platforms:			
	Task 1: Methods for calibrating echosounders on fishing vessels	Short	Dr Macaulay, Dr Fielding	
	Task 2: Survey design for fishing fleets	Short	Linked to 1.a.i	
	Task 3: Develop the use of krill length frequency data in the estimation of target strength and krill weight for biomass estimates	Short	Dr Cox, Dr Zhao	
	(iii) Data collection – SISO, vessels and CEMP Specification for sample size and the use of krill length frequency data	Short	Annex 4, Table 2, 1.a.ii and 1.a.iv.4	Yes
	(iv) Acoustic data storage and processing			
	(1)(A) Identify metadata (B) Acoustic raw data storage requirements and processing	Short	ASAM	Yes
	(2) Automated data processing of acoustic data from fishing vessels, including frequency of updates to biomass updates	Long	Dr Menze, Dr Wang, Dr Fielding	
	(3) Standardised procedures to check and verify acoustic data	Medium	Dr Macaulay	
	(4) Develop the use of krill length frequency data in the estimation of target strength and krill weight for biomass estimates, including seasonal and regional effects of developmental stage	Medium	Dr Cox, Dr Wang	Yes
	(5) Submission of acoustic data and the inclusion of metadata by Members in the repository held by the Secretariat	Annual	Annex 4, Table 2, 1.a.iv.1	
	(6) Develop statistical approaches to acoustic data emerging from new acoustic observation platforms	Long	Dr Reiss, Dr Menze, Dr Dornan	
	(v) Biomass estimation			
	(4) Krill biomass estimate in Division 58.4.1	Long	Dr Cox, Dr Murase	
	(5) Krill biomass estimate in Division 58.4.2	Long		
	(b) Develop stock assessments to implement decision rules for krill			
	(i) Krill management approach (biomass estimates)			
	(1) Subarea 48.1	Short		
	(2) Subarea 48.2 etc.	Short	ASAM	
	(ii) Develop diagnostic tools			

(continued)

Table 2 (continued)

Theme	Topic/task	Timeframe	Contributors	Secretariat participation
	(iii) Develop ecosystem indicators to inform risk assessment framework			
	(iv) Methods to account for uncertainty in stock status			
	(1) Movement of krill (flux)	Medium	Dr Kasatkina	
	(2) Spatial structure within subareas		Dr Ying	
	(3) Interannual variability			
	(c) Develop methods to estimate biomass for finfish			
	(i) Survey design	Medium	Dr Kasatkina	
	(ii) Data collection – SISO and vessels			
	(iii) Improve biomass estimation methods	Long	Dr Wang	
2. Ecosystem impacts	(a) Ecosystem monitoring (Second Performance Review, recommendation 5)			
	(i) Structured ecosystem monitoring programs (CEMP, fishery)			
	(1) CEMP			
	(2) Fishery via SISO			
	(3) Research surveys			
	(b) Monitoring and adaptation to effects of climate change (see Table 2. SC-CAMLR-41/10)	Medium		
	(i) Develop methods to detect change in ecosystems given variability and uncertainty			
	(1) autonomous platforms		Dr Dornan	
Administrative topics	(a) Advise on database facilities required throughout DSAG	Annex 4, Table 2, 1.a.iv		
	(b) Advise on quality control and assurance processes for data provided to and supplied by the Secretariat	Annex 4, Table 2, 1.a.iv		
	(c) Refine SISO across all fisheries	Annex 4, Table 2, 1.a.iv		
	(d) Further develop data management systems	Annex 4, Table 2, 1.a.iv		
	(e) Communication of progress, internal and external			
	(f) Working group terms of reference	2022		
	(g) Scientific Committee Symposium in 2027			

Appendix A

List of Participants

Working Group on Acoustic Survey and Analysis Methods
(Tokyo, Japan, 21 to 26 May 2023)

Co-convener	Dr Sophie Fielding (did not attend the meeting) British Antarctic Survey
Co-convener	Dr Xinliang Wang Yellow Sea Fisheries Research Institute, Chinese Academy of Fishery Science
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Ukraine	Mr Viktor Podhornyi Institute of Fisheries and Marine Ecology (IFME) Dr Leonid Pshenichnov Institute of Fisheries and Marine Ecology (IFME) of the State Agency of Melioration and Fisheries of Ukraine
United Kingdom	Dr Tracey Dornan British Antarctic Survey
CCAMLR Secretariat	Daphnis De Pooter Science Data Officer Dr Steve Parker Science Manager

Appendix B

Agenda

Working Group on Acoustic Survey and Analysis Methods
(Tokyo, Japan, 22 to 26 May 2023)

1. Introduction

    1.1 Opening of the meeting
    1.2 Adoption of the Agenda

2. Review Terms of Reference and workplan

3. Standardised procedures for acoustic surveys and development of krill biomass estimates

    3.1 Collection, processing and reporting of acoustic data
    3.2 Storage of acoustic data

4. Collection and analysis of acoustic data on board fishing vessels

    4.1 Methods for calibrating echosounders on fishing vessels
    4.2 Survey design and data collection for fishing vessels
    4.3 Krill biological data collection

5. Krill biomass estimates

    5.1 Area 48 biomass estimates
    5.2 Area 58 biomass estimates

6. Survey design and using other platforms

7. Develop methods to estimate biomass of finfish using acoustic techniques

8. Future work

9. Other business

10. Advice to the Scientific Committee

11 Adoption of report and close of meeting.

Appendix C

List of Documents

Working Group on Acoustic Survey and Analysis Methods
(Tokyo, Japan, 22 to 26 May 2023)

WG-ASAM-2023/01	Standardised rules for georeferenced polygons and lines Secretariat
WG-ASAM-2023/02	Using automatic open-source analysis of backscatter data from fishing vessels to implement feedback management of the Antarctic krill fishery S. Menze, G.J. Macaulay, G. Zhang, A. Lowther and B.A. Krafft
WG-ASAM-2023/03	Preliminary results of a local acoustic-trawl survey of *Champsocephalus gunnari* in Statistical Subarea 48.2 L. Pshenichnov, V. Podhornyi and K. Demianenko
WG-ASAM-2023/04	Temporal patterns in South Georgia (48.3) zooplankton: insights from a moored echosounder T. Dornan, S. Fielding and G.A. Tarling
WG-ASAM-2023/05	Echosounder settings and calibration parameters for New Zealand fishing vessels, 2009–2022 A. Wieczorek, Y. Ladroit, P. Escobar-Flores, R O'Driscoll and J. Devine
WG-ASAM-2023/06	Acoustic determination of Antarctic krill biomass at South Georgia (Subarea 48.3) during winter C.M. Liszka, S. Fielding, T. Dornan and M.A. Collins
WG-ASAM-2023/07	Some parameters for consideration regarding improvement of the CCAMLR protocol for calculating krill biomass G. Zhang, G. Skaret, R. Pedersen, S. Menze and B.A. Krafft
WG-ASAM-2023/08	Calibration of echosounders for biomass estimation using seafloor backscattering at fixed transects G. Macaulay, S. Menze and B. Krafft
WG-ASAM-2023/09	Repository of acoustic data collected by fishing vessels along CCAMLR nominated transects Secretariat

WG-ASAM-2023/10	Some corrections to Table 2 of WG-ASAM-2021/06 (Abe et al., 2021) K. Abe, R. Matsukura, N. Yamamoto, K. Amakasu, R. Nagata and H. Murase

Other Documents

WG-ASAM-2023/P01	Two scales of distribution and biomass of Antarctic krill (*Euphausia superba*) in the eastern sector of the CCAMLR Division 58.4.2 (55°E to 80°E) M.J. Cox, G. Macaulay, M.J. Brasier, A. Burns, O.J. Johnson, R. King, D. Maschette, J. Melvin, A.J.R. Smith, C.K. Weldrick, S. Wotherspoon and S. Kawaguchi PLOS ONE, 17(8): e0271078 (2022), doi: https://doi.org/10.1371/journal.pone.0271078
WG-ASAM-2023/P02	Per-length biomass estimates of Antarctic krill (Euphausia superba) A.J. Smith, S. Wotherspoon and M.J. Cox *Front. Mar. Sci., Sec. Marine Ecosystem Ecology*, 10 (2023), doi: https://doi.org/10.3389/fmars.2023.1107567
WG-ASAM-2023/P03	Volume backscattering spectra measurements of Antarctic krill using a broadband echosounder N. Yamamoto, K. Amakasu, K. Abe, R. Matsukura, T. Imaizumi, T. Matsuura and H. Murase *Fish. Sci.*, 89 (2023): 301–315, doi: https://doi.org/10.1007/s12562-023-01678-6

Appendix D

Instruction manual for the collection of fishing vessel-based acoustic data

Version 2.0

Preface

This manual is to be used by the person(s) who are responsible for the collection of raw acoustic data on board krill fishing vessels operating in the CAMLR Convention Area. The specific instruments covered by this manual are limited to Simrad ES60, Simrad ES70, Simrad EK60, Simrad ES80 and Simrad EK80 echosounders.

The data collected according to this manual, whether during specially designed surveys along nominated transits or during fishing operations (including searching for suitable fishing aggregations and steaming to another fishing area), are potentially very valuable and may be used to provide qualitative and quantifiable information on the distribution and relative abundance of Antarctic krill (*Euphausia superba*). This information is fundamental to CCAMLR's approach to management.

The manual consists of:

Chapter 1: A brief overview of what data should be collected, where and when they should be collected and finally how they should be collected.

Chapter 2: Data logging instructions.

Chapter 3: Validation of instrument performance.

Chapter 4: An overview of metadata to accompany data submissions to the Secretariat.

For further details, please contact your national technical coordinator or Scientific Committee Representative or contact the CCAMLR Secretariat (ccamlr@ccamlr.org).

Thank you for taking the time to record these important data.

Chapter 1

A brief overview of recommendations for data collection

What data should be collected: Raw acoustic data and supporting metadata describing the acoustic data, the acoustic instruments and cruise should be collected. The actual acoustic data needs to have the correct metadata (the data that describe the data) in order to be useable.

Where data should be collected: Acoustic data, together with supporting metadata, should be collected in all of the areas for which the vessel has been licenced to fish for krill. The acoustic data collected along the nominated transects (highlighted in bold in Table 1 and Figure 1), as well as in the areas in which fishing actually occurs, are a high priority.

When data should be collected: Acoustic data collection should begin as the vessel enters the Convention Area and be continued until the vessel leaves. Collecting data throughout the entire fishing trip is a prerequisite for building a picture of temporal variability in krill abundance and distribution. In particular, given the importance of the nominated transects in building patterns of temporal variability, repeating these nominated transects as often as possible during the cruise is recommended.

How data should be collected: Raw acoustic data should be logged to a hard drive. The echosounder should be configured using the key settings detailed in Table 2.

Table 1: Waypoints (dd mm.00) of the acoustic transects that are part of existing krill acoustic surveys in Subareas 48.1, 48.2 and 48.3 with the nominated transects highlighted in bold. Maps showing the location of the nominated transects are in Figure 1.

Subarea	Transect	Waypoint 1		Waypoint 2	
		Longitude	Latitude	Longitude	Latitude
48.1	T1	63°00.00'W	62°15.00'S	62°00.00'W	62°45.00'S
	T2	**62°30.00'W**	**62°00.00'S**	**61°30.00'W**	**62°30.00'S**
	T3	**62°00.00'W**	**61°45.00'S**	**61°00.00'W**	**62°15.00'S**
	T4	61°30.00'W	61°30.00'S	60°00.00'W	62°15.00'S
	T5	61°00.00'W	61°15.00'S	59°30.00'W	62°00.00'S
	T6	60°30.00'W	61°00.00'S	59°00.00'W	61°45.00'S
	T7	58°30.00'W	60°00.00'S	58°30.00'W	61°30.00'S
	T8	57°30.00'W	60°00.00'S	57°30.00'W	61°45.00'S
	T9	57°00.00'W	60°00.00'S	57°00.00'W	61°45.00'S
	T10	56°30.00'W	60°00.00'S	56°30.00'W	61°45.00'S
	T11	55°45.00'W	60°00.00'S	55°45.00'W	61°45.00'S
	T12	55°00.00'W	60°00.00'S	55°00.00'W	61°03.00'S
	T13	**54°30.00'W**	**60°00.00'S**	**54°30.00'W**	**61°45.00'S**
	T14	**54°00.00'W**	**60°00.00'S**	**54°00.00'W**	**61°03.00'S**
	T15	61°30.00'W	63°00.00'S	60°30.00'W	63°30.00'S
	T16	**60°30.00'W**	**63°00.00'S**	**59°30.00'W**	**63°30.00'S**
	T17	**60°00.00'W**	**62°45.00'S**	**59°00.00'W**	**63°15.00'S**
	T18	59°30.00'W	62°30.00'S	58°30.00'W	63°00.00'S
	T19	58°30.00'W	62°30.00'S	57°30.00'W	63°00.00'S

(continued)

Table 1 (continued)

Subarea	Transect	Waypoint 1		Waypoint 2	
		Longitude	Latitude	Longitude	Latitude
	T20	58°00.00'W	62°15.00'S	57°00.00'W	62°45.00'S
	T21	57°24.00'W	62°00.00'S	56°30.00'W	62°30.00'S
	T22	56°00.00'W	62°00.00'S	56°00.00'W	62°45.00'S
	T23	55°00.00'W	61°12.00'S	55°00.00'W	63°00.00'S
	T24	54°00.00'W	61°18.00'S	54°00.00'W	62°45.00'S
48.2	T1	48°30.00'W	59°40.20'S	48°30.00'W	62°00.00'S
	T2	47°30.00'W	59°40.20'S	47°30.00'W	62°00.00'S
	T3	**46°30.00'W**	**59°40.20'S**	**46°30.00'W**	**62°00.00'S***
	T4	**45°45.00'W**	**59°40.20'S**	**45°45.00'W**	**60°28.80'S**
	T5	45°00.00'W	59°40.20'S	45°00.00'W	60°36.60'S
	T6	44°00.00'W	59°40.20'S	44°00.00'W	62°00.00'S
	T7	45°45.00'W	60°42.00'S	45°45.00'W	62°00.00'S
	T8	45°00.00'W	60°58.80'S	45°00.00'W	62°00.00'S
48.3	T1	39°36.14'W	53°20.83'S	39°23.51'W	54°03.32'S
	T2	39°18.25'W	53°18.94'S	39°05.34'W	54°01.40'S
	T3	39°02.29'W	53°17.22'S	38°49.14'W	53°59.64'S
	T4	38°45.05'W	53°15.31'S	38°31.61'W	53°57.70'S
	T5	**38°26.94'W**	**53°13.25'S**	**38°13.22'W**	**53°55.61'S**
	T6	**38°08.42'W**	**53°11.11'S**	**37°54.40'W**	**53°53.42'S**
	T7	37°57.86'W	53°09.85'S	37°43.67'W	53°52.15'S
	T8	37°49.93'W	53°08.90'S	37°35.62'W	53°51.19'S
	T9	**36°15.62'W**	**54°05.73'S**	**35°15.19'W**	**53°41.49'S**
	T10	**36°10.50'W**	**54°10.35'S**	**35°09.80'W**	**53°46.26'S**
	T11	36°04.15'W	54°15.94'S	35°03.05'W	53°51.92'S
	T12	35°57.60'W	54°21.02'S	34°57.42'W	53°56.79'S
	T13	35°54.68'W	54°24.11'S	34°53.74'W	53°59.99'S
	T14	35°48.65'W	54°29.60'S	34°47.35'W	54°05.35'S
	T15	35°43.98'W	54°33.43'S	34°42.54'W	54°09.38'S
	T16	35°38.65'W	54°38.34'S	34°36.98'W	54°14.02'S
	T17	35°33.94'W	54°42.22'S	34°32.50'W	54°18.15'S
	T18	35°29.00'W	54°46.67'S	34°26.85'W	54°22.33'S

* Only the northern section (from 59°40.20'S to 60°28.80'S) is a nominated transect.

(a)

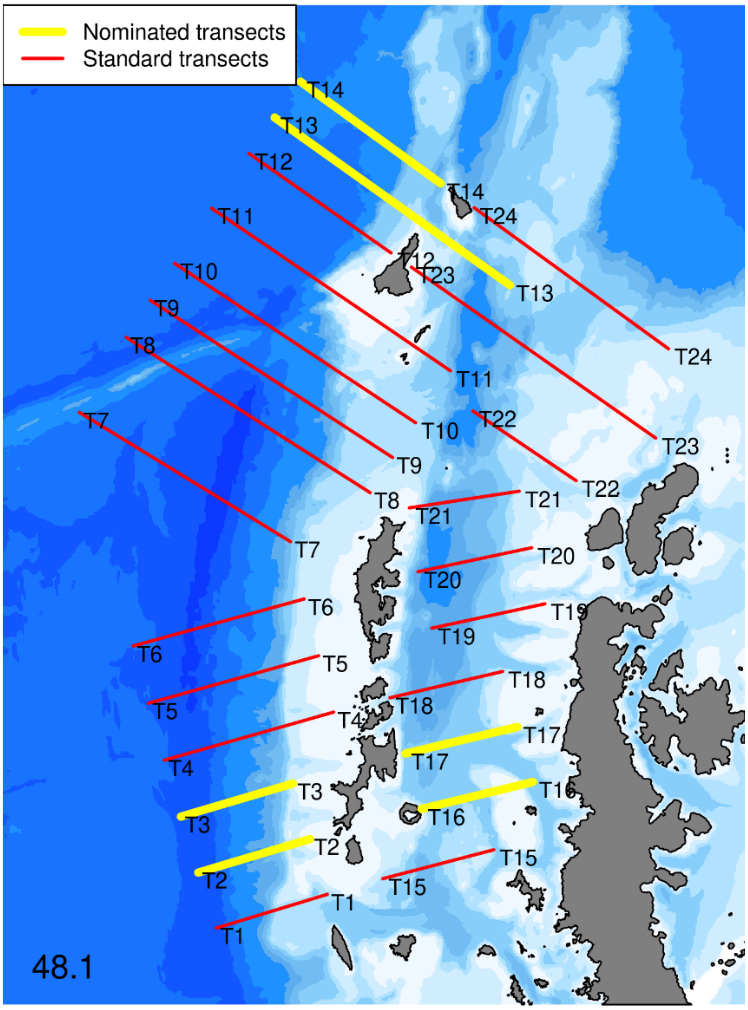
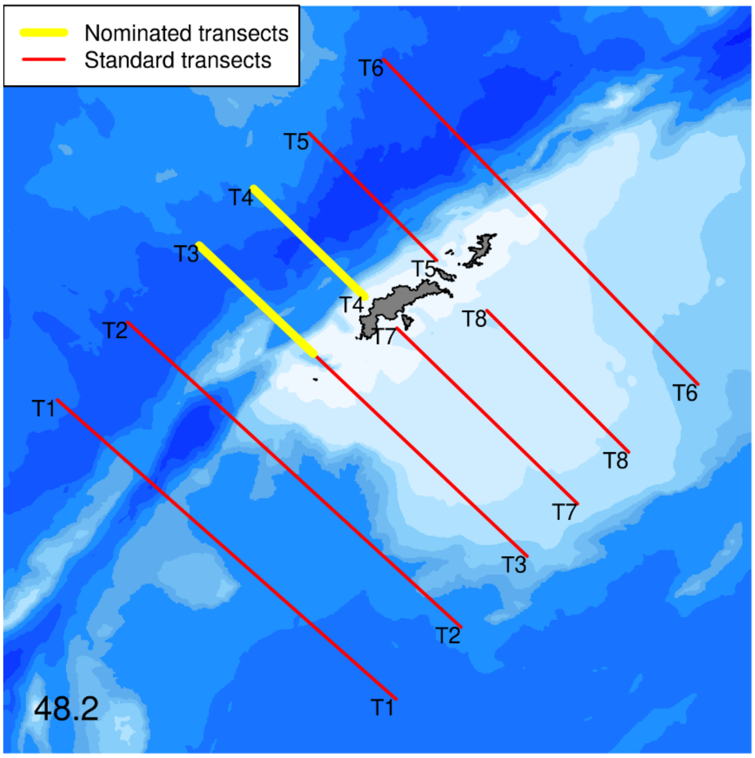


Figure 1: Location of nominated transects (thick yellow lines) and existing research transects for the collection of acoustic data in: (a) Subarea 48.1.

(continued)

(b)



(c)

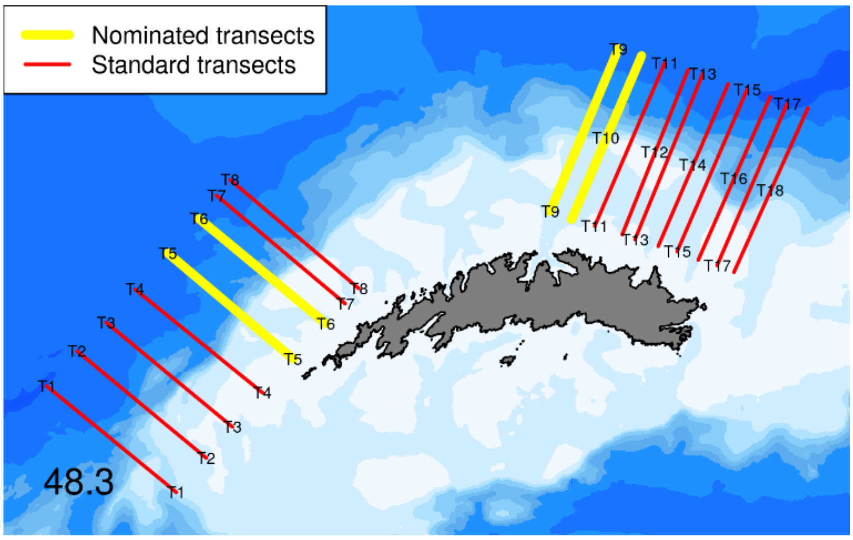


Figure 1 (continued): Location of nominated transects (thick yellow lines) and existing research transects for the collection of acoustic data in: (b) Subarea 48.2 and (c) Subarea 48.3.

Chapter 2

Data logging instructions

2.1. System requirements

Vessels are encouraged to regularly update the data acquisition software.

2.1.1 Echosounder

These instructions apply to Simrad ES60, Simrad ES70, Simrad EK60, Simrad ES80 or Simrad EK80 echosounders. A global positioning system (GPS) (with data output) should be connected to the echosounder. Please refer to the instruction manual of your echosounder to properly configure it according to the settings specified in this chapter.

2.1.2 Data logging device

An external hard drive with a minimum data storage capacity of 2 Tb. The actual volume of data stored depends on the number of frequencies used and the duration of the time in the Convention Area. The data should be stored as Power/Angle samples (ES80 and EK80). The file name should ideally have a unique vessel identifier (e.g. International Maritime Organization (IMO) number) and the instrument type (e.g. EK80) as prefix.

2.2 Instrument parameter settings

2.2.1 The instrument parameters should be set according to Table 2 and should not be changed, except the display range.

Table 2: Instrument setting for data collection.

Parameter	Unit	Setting			
Frequency	kHz:	38	70	120	200
Power[1]	W	2000	700	250	110
Pulse type[2]		CW	CW	CW	CW
Pulse duration	Microsecond	1024	1024	1024	1024
Ping interval	Second	2	2	2	2
Data collection range (min.–max.)	M	0–1100	0–1100	0–1100	0–1100
Bottom detection range (min.–max.)	M	5–1100	5–1100	5–1100	5–1100
Display range (min.–max.)	M	0–1100	0–1100	0–1100	0–1100

[1] Based on Korneliussen et al., 2008.
[2] Only for EK80 and ES80.

2.3 Operational instructions

- Please ensure your echosounder is operating in Coordinated Universal Time (UTC).
- Please ensure you log the acoustic data.
- The file size for storing acoustic data should be set to 100 MB.
- Where possible, other echosounders (except navigational echosounders) should be turned off to avoid unwanted interference.
- Please record the instrument and calibration attributes listed in Chapter 4 before data collection.
- When collecting data along transects:
  - pass through the waypoints of the transects in Table 1 in as straight a line as you can undertake. Transects can be undertaken in either direction (e.g. from N to S or vice versa)
  - maintain a constant vessel speed, ideally at 10 knots, that allows low noise data collection
  - please record the transect attributes listed in Chapter 4 at the beginning or end of each transect.

Chapter 3

Validation of instrument performance

3.1 External assessment of echosounder performance

3.1.1 Standard sphere calibration

If possible, carry out a standard sphere calibration utilising the techniques described in Foote et al. (1987) and ICES (2015). Locations where regular calibrations have been carried out previously are given in Table 3.

Table 3: Positions (dd mm.00) of regularly used calibration sites in Subareas 48.1, 48.2 and 48.3.

Subarea	Calibration site	Position	
		Longitude	Latitude
48.1	Admiralty Bay	58°26.58'W	62°08.10'S
48.2	Scotia Bay	44°40.86'W	60°44.88'S
48.3	Stromness Bay	36°40.02'W	54°09.30'S

3.1.2 Seabed reflection calibration

CCAMLR is currently investigating the use of seabed reflection as another way of externally assessing echosounder performance. A protocol for such assessments will be added to this part of the document once it becomes available.

3.2 Internal assessments of echosounder performance on board of vessels

Internal validation procedures to monitor basic system performance are being developed. Vessels running EK80 or ES80 systems are encouraged to perform built-in self-test equipment (BITE – accessed through the diagnostics dialog box) diagnostics and provide the result by filling in Table 4 or providing a screenshot of the test (Figure 2).

Table 4: BITE diagnostics table.

Transducer serial number						
Transducer frequency (kHz)						
Channel 1:	Impedence		Ohm	Phase		°
Channel 2:	Impedence		Ohm	Phase		°
Channel 3:	Impedence		Ohm	Phase		°
Channel 4:	Impedence		Ohm	Phase		°

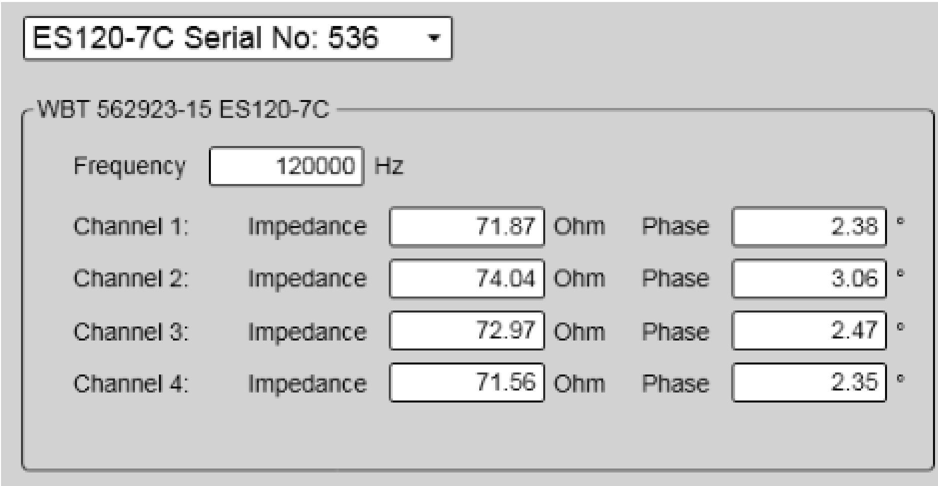


Figure 2: Example of impedance screenshot from a 120 kHz split-beam transducer using the BITE functionality of ES80 software.

Chapter 4

Data reporting and submission

Metadata contain important information that is an essential element of the data logged and should be delivered with the data collected.

Please record the data in Tables 5 and 6 prior to data collection. When data have been collected along nominated transects as listed in Table 1 and shown in Figure 1, please also record the relevant metadata in Table 7.

Please contact your national technical coordinator or Scientific Committee Representative regarding the submission of data to the Secretariat.

Table 5: Cruise metadata required to accompany acoustic data submissions to the Secretariat.

Parameter	Definition
Vessel name	The name of the vessel
Vessel IMO	The IMO number of the vessel
Cruise start date	The date the vessel left port
Cruise end date	The date the vessel returned to port

Table 6: Instrument and calibration attributes recommended to accompany acoustic data submissions to the Secretariat (adapted from SC-CAMLR-41, Annex 5, Table 2).

Parameter	Definition
Operating frequency (kHz)	Frequency of the transceiver/transducer combination in kHz. Some systems, such as broadband and multibeam, will have a range of frequencies. If so, specify the minimum, maximum and centre frequency
Transducer location	Location of installed transducer. Refer to ICES SISP 4-TG-AcMeta Appendix B.2 for a list of standard transducer locations
Transducer manufacturer	Transducer manufacturer
Transducer model	Transducer model
Transducer depth (m)	Mean depth in metres of transducer face beneath the water surface
Transducer orientation	Direction perpendicular to the face of the transducer. A simple description for a ship mounted sounder would be ‘downward-looking’, a mooring could be ‘upward-looking’. If required, ICES SISP 4-TG-AcMeta Appendix C provides a comprehensive description of transducer orientation conventions
Transducer equivalent beam angle (dB)	Manufacturer-specified transducer equivalent beam angle in dB, expressed as $10\log10(\Psi)$, where Ψ has units of steradians
Transducer beam angle major (degrees)	Major beam opening in degrees, also referred to as ‘athwartship angle’. See ICES SISP 4-TG-AcMeta Appendix D for description of beam geometry conventions
Transducer beam angle minor (degrees)	Minor beam opening in degrees, also referred to as ‘alongship angle’. See ICES SISP 4-TG-AcMeta Appendix D for description of beam geometry conventions
Transceiver manufacturer	Transceiver manufacturer
Transceiver model	Transceiver model
Transceiver serial	Transceiver serial number

(continued)

Table 6 (continued)

Parameter	Definition
Transceiver firmware version	Transceiver firmware version
Calibration date	Date and time of calibration
Calibration method	Describe the method used to acquire calibration data (see ICES SISP 4-TG-AcMeta Appendix B.4, Standard lists)
Calibration processing method	Describe method of processing that was used to generate calibration offsets
Calibration accuracy estimate	Estimate of calibration accuracy. Include a description and units so that it is clear what this estimate means (e.g. estimate might be expressed in dB or as a percentage)
Calibration location	Name of the site where the calibration was carried out. See also Table 3
Acquisition software name	Name of software that controls the echosounder and its data logging
Acquisition software version	Version of software that controls the echosounder and its data logging

Table 7: Transect attributes recommended to accompany acoustic data submissions to the Secretariat (adapted from ICES SISP 4-TG-AcMeta standard and WG-ASAM-2021/15, Table 1).

Parameter	Definition
Subarea	The subarea in which the transect was conducted. For example, 48.1, 48.2 or 48.3
Transect number	The number of the transect as defined in Table 1
Start datetime (UTC)	Start date and time in UTC of the transect formatted following ISO 8601. For example, 18:00 UTC on 24 October 2008 would be represented as 2008-10-24T18:00:00
End datetime (UTC)	End date and time in UTC of the transect formatted following ISO 8601. For example, 18:00 UTC on 24 October 2008 would be represented as 2008-10-24T18:00:00
Start latitude	The latitude of the start of the transect expressed in decimal degrees
Start longitude	The longitude of the start of the transect expressed in decimal degrees
Start heading	The heading at the start of the transect expressed in degrees
Start course	The course at the start of the transect expressed in degrees
Start depth (m)	The bottom depth in meters at the start of the transect
Start speed (kn)	The speed of the vessel in knots at the start of the transect
Start wind direction	The wind direction at the start of the transect expressed in degrees
Start wind speed (kn)	The wind speed in knots at the start of the transect
Start sea state	The state of the sea at the start of the transect using World Meteorological Organization (WMO) Sea State Codes
End latitude	The latitude of the end of the transect expressed in decimal degrees. Positive values are north of the equator, negative values are south of the equator
End longitude	The longitude of the end of the transect expressed in decimal degrees. Positive values are east of the Greenwich Meridian, negative values are west of it
End heading	The heading at the end of the transect expressed in degrees
End course	The course at the end of the transect expressed in degrees
End depth (m)	The bottom depth in meters at the end of the transect
End speed (kn)	The speed of the vessel in knots at the end of the transect
End wind direction	The wind direction at the end of the transect expressed in degrees
End wind speed (kn)	The wind speed in knots at the end of the transect
End sea state	The state of the sea at the end of the transect using WMO Sea State Codes
Transect comments	Free text field for relevant information that might not be captured by the defined attributes

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.

ICES. 2015. Calibration of acoustic instruments. *ICES Coop. Res. Rep.*, 326: 136 pp, doi: https://doi.org/10.17895/ices.pub.5494.

Korneliussen, R.J., N. Diner, E. Ona, L. Berger and P.G. Fernandes. 2008. Proposals for the collection of multifrequency acoustic data. *ICES J. Mar. Sci.*, 65: 982–994.

Appendix E

Krill biomass estimate workflow – WG-ASAM-2023

Please see 'ASAM_2023_KrillBiomassStats_CombV3.Rmd', which is the accompanying RMarkdown document.

1. Read in metadata table "ASAM_metadata_2022_v1_tidy.csv"

2. Consolidate survey names

Recode survey areas to the nearest available new strata.
Strata were allocated a strata_code to the 4 AMLR areas (E, W, S and J based on geographic location).
3 new areas were added in 2022 – DP, GS and PB.

Stratum_name	Number_surveys	strata_code
Elephant Island	31	E
West	31	W
South	26	S
Joinville	14	J
Bransfield	2	S
South Shetland Islands North	1	W
South Shetland Island (SSI)	1	W
Bransfield Strait (BS)	6	S
Elephant Island (EL)	1	E
DP	1	DP
PB	1	PB
GS	1	GS

3. Remove Duplicate and Bad data

As analysis requires Density (g m^{-2}), CV, and Area, for weighted density calculations:

1. Remove rows which do not have complete records for 'Density' and/or 'CV' or where values other than CV were reported (i.e. confidence intervals).
2. Remove anything with a comment in the 'ASAM_NOTES' because this was either:
    a. the same AMLR data but run with the Greene algorithm so DUPLICATED
    b. incomplete/the area was not covered properly so difficult to weight appropriately.
3. Remove rows where area was not recorded.

NOTE: When running the RMarkdown script removed files are stored in a 'remdat' data table.

4. R friendly format

1. Ensure all numeric values are stored as class numeric.
2. Create a year-month timestamp for plotting.
3. Create a 'season' year variable where survey values collected in 'Oct-Dec' are annotated as the year of collection +1.

5. Calculate the Std. deviation (S.*D. density*) and variance of density (*Var. density*) for each survey (i)

$$S.D.\ density_i = Density_i * \frac{CV_i}{100}$$

$$Var.\ density_i = (S.D.\ density_i)^2$$

6. Calculate 95% Confidence Intervals of each survey for plotting, assuming a lognormal distribution

qlnorm(p=0.025, meanlog=log(Density$_i$), sdlog=sqrt(log(1+(CV$_i$/100)^2)))

qlnorm(p=0.975, meanlog=log(Density$_i$), sdlog=sqrt(log(1+(CV$_i$/100)^2)))

7. Update Subarea 48.1 strata values from WG-ASAM-2023/01

1. Subset to metadata to Subarea 48.1.
   Subarea strata codes "E" = Elephant, "J" = Joinville, "W" = SSIP, "S" = Bransfield Strait, "GS" = Gerlache Strait, "PB" = Powell Basin, "DP" = Drake Passage.
2. Update areas from WG-ASAM-2023/01 'AMLR_Area'.

8. Calculate annual biomass for each new stratum and season

1. Subset surveys by 'Strata' e.g. 'J', and sampling 'Season' e.g. '2019'.

2. Assign each survey an area weighting ($areawt_i$) based on the $area_i$ of each survey, divided by the sum of all survey areas within the Strata Season subset:

$$areawt_i = \frac{area_i}{\sum_{i=1}^{n} area_i}$$

where *n* is the total number of surveys within the strata and season subset.

3.1 Calculate weighted mean density ($wtDensity$, g m^{-2}) for each Strata and Season using the *weighted.mean* function in R where:

x = vector of $Density_i$

w = vector of $areawt_i$

3.2 Calculate the weighted mean variance ($wtVar.density$) of density for each Strata and Season, using the *weighted.mean* function in R where:

x = vector of $Var.density_i$

w = vector of $areawt_i$

3.3 Calculate the weighted mean *CV* ($wtCV$) for each Strata and Season, using the *weighted.mean* function in R where:

x = vector of CV_i

w = vector of $areawt_i$

NOTE: where the total number of surveys in a single stratum and survey season = 1, the weighting will equal 1 and the weighted mean density, variance and CV will be unchanged from the density and CV given in the original survey.

4. Define new area for strata ($StrataArea$)

5. Calculate krill biomass (tonnes) for each Strata and Season as:

$$Biomass = wtDensity * StrataArea$$

6. Calculate variance of biomass for each Strata and Season as:

$$Var = wtVar.density * StrataArea^2$$

7. Calculate the *CV* of Biomass (tonnes), where:

$$CV = \frac{\sqrt{Var}}{Biomass} \times 100$$

9. Average across all available years 'yall'

Biomass estimates for each stratum are the mean of all available years.

10. Use R qlnorm to calculate the one-sided lower 95% confidence bound of density (*LB95*).

qlnorm(p=0.025, meanlog=log($wtDensity$), sdlog=sqrt(log(1+(sqrt($wtVar.density$)/ $wtDensity$)^2)))

11. Calculate the one-sided lower 95% biomass for use in strata with only one survey.

$$LB95\_Biomass = LB95 * StrataArea$$