Rapport fra Havforskningen
ISSN 1893-4536 (online)
Nr. 16-2018

Antarctic krill and ecosystem monitoring survey off the South Orkney Islands in 2018

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Project Report

Report:
RAPPORT FRA HAVFORSKNINGEN

No. – Year:
16-2018

Date:
09.05.2018

Title (Norwegian and English):
Antarktisk krill og økosystemovervåkning ved Sør Orknøyene i 2018

Antarctic krill and ecosystem monitoring survey off the South Orkney Islands in 2018

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Distribution: Open

Project no.: 14246

Assignor(s): Institute of Marine Research

Program:
Marine Processes and Human Impact

Research group:
Plankton

Number of pages in total:
222

Summary (Norwegian):
Miljøovervåking langs faste snitt ved Sør Orknøyene, i Sørishavet. Gjennomført årlig tokt (siden 2011) for å samle inn akustiske og biologiske data på krill, annen makro-zooplankton samt data om krillpredatorer fra sektor 48.2 i Sørishavet.

Summary (English):
Environmental monitoring along set transect lines off South Orkney Islands, Southern Ocean. Executed annual surveys (since 2011) to collect acoustic and biological data on krill, other macro zooplankton and data on krill predators from sector 48.2 in the Southern Ocean.

Emneord (norsk):
1. krill
2. Sørishavet

Subject heading (English):
1. Krill
2. The Southern Ocean

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Content

1 Introduction and background

The fishing operations for Antarctic krill (*Euphausia superba*) are concentrated within CCAMLR (Commission on the Conservation of Antarctic Marine Living resources) subareas 48.1, 48.2 and 48.3 in the Southern Ocean. Due to limited knowledge about this marine ecosystem and the potential negative effects of fishery activities, a precautionary catch limit for the Scotia Sea (48.1-48.4) was set at 620,000 tons by CCAMLR in 1991.

The total krill catch for 2017 was 237 450 tons (63% in 48.1, 29% in 48.2 and 8% in 48.3). Regular monitoring of the krill during the last two decades has been carried out by US AMLR in the Bransfield Strait and Elephant Island (subarea 48.1), previously at austral summer time but presently at austral winter time, as well as the British Antarctic Survey off the South Georgia Islands (subarea 48.3) during the austral summer season. The Norwegian fishing company Aker Biomarine ASA offered to carry out an annual krill monitoring survey commencing in 2011, for as long as they have commercial activity in the Southern Ocean (Jensen et al. 2010). Through discussions in CCAMLR WG-EMM (Working Group on Ecosystem Monitoring and Management) in 2010, it was agreed that the survey could be carried out in the CCAMLR statistical Subarea 48.2 according to similar standards as the annual scientific surveys undertaken in 48.1 and 48.3. Together the three surveys could form an integrated monitoring effort extending across the Scotia Sea and linking three of the areas with highest concentrations of krill and highest fishing activity. In 2012, the other Norwegian operating company, Olympic ASA, adhered to the agreement. The first annual survey was carried out in January/February 2011 using the FV 'Saga Sea' (Aker Biomarine ASA), with scientists from the Norwegian Institute of Marine Research. The results and study design from this survey was presented at the CCAMLR WG-EMM in 2011.

The original survey design, which was suggested during the WG-EMM meeting in 2010, consisted of six parallel north-south bound transects extending 100 nmi each. During this first survey season it was recognized a need to extend the monitoring effort covering the waters over the shelf edge, north of the South Orkney archipelago, where most krill in this region traditionally aggregate. During the WG-EMM meeting in 2011 it was agreed to extend the survey transects 20 nmi northwards and to omit the westernmost transect line from the 2011 survey. Before the survey in 2014, it was also agreed to extend the transect lines further to the south to cover the northern part of the Marine Protected Area south of the South Orkney Islands, and the design has since remained unchanged. This report presents the results from the eight of the annual survey seasons (2018) off the South Orkney Islands including results from continuous acoustic recordings, trawl station data and krill predator sighting data collected during daylight hours along the transects. In addition, on board experiments investigating krill behaviour in relation to the development of harvesting technology were conducted. These experiments were part of the project “Understanding and predicting size selectivity and escape mortality in commercial Zooplankton fisheries: case study on Antarctic krill”. As monitoring platform, the krill fishing vessel ‘Juvel’ was used, now owned by the Norwegian company Aker Biomarine (recently changed owner from Olympic ASA).

2 Material and methods

2.1 Survey design, area and vessel

The FV “Juvel” (Aker Biomarine ASA) departed Montevideo, Uruguay, on the 28 January. On the 4 February, the transect-survey commenced, and it ended on the 10 February. The vessel returned to Montevideo on the 16 February. The survey design around the South Orkney Islands included five parallel transects extending from the northernmost waypoints at 59.67°S and southernmost waypoint at 62.00°S. Longitudes for transects 1 through 5 are at 44°W, 45°W, 45.75°W, 46.5°W and 47.5° W, respectively.

Echo sounder calibration was carried out under good conditions (low wind and sea-state) in Scotia Bay, Laurie Island, and the two moorings deployed last year was recuperated east of the ‘Little Canyon’.

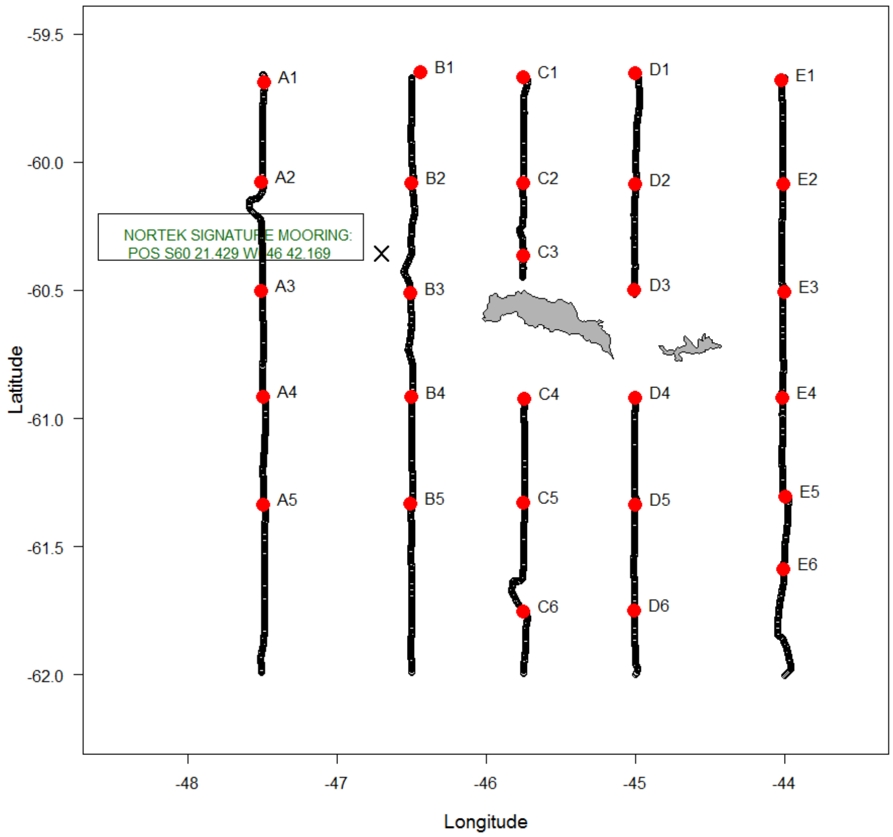

Figure 1. *Summary of the 2018 krill monitoring survey. The black lines denote the transect lines. The red circles indicate the trawl stations. The black cross marks the position where the NorTek mooring was deployed.*

2.2 Acoustic data collection

2.2.1 Vessel mounted echo sounders

'Juvel' is equipped with Simrad ES60 echo sounders operating at 38, 70 and 120 kHz. These are the fishery versions of the scientific Simrad EK60. We replaced the original ES60 transceivers with scientific EK60 transceivers (GPTs) prior to the survey.

The echo sounders were calibrated in Scotia Bay off the Argentinian Orcadas base on the southside of Laurie Island using standard sphere calibration (Foote et al., 1987). The echo sounder was operating with a ping interval at or close to 1 per second. Nominal vessel speed during surveying is 10 knots, and could be kept during most of the survey. On some occasions speed was reduced to 8 knots to reduce the impact of swell during bad weather. Acoustic data were collected down to 750 m on all three frequencies. Other transceiver settings are specified in Table 1.

Table 1. *Specification of transceiver settings on 'Juvel' applied during the 2018 survey.*

Echosounder specification	38 kHz	70 kHz	120 kHz
Transducer type	ES38-B	ES70-B	ES120
Transmitted power (W)	2000	700	250
Pulse duration (ms)	1.024	1.024	1.024
Absorption coefficient (dB km^{-1})	9.9	17.8	25.8
Sound speed (ms^{-1})	1453	1453	1453
Sample distance (m)	0.186	0.186	0.186
Two-way beam angle (dB)	-20.6	-21.0	-21
S_v transducer gain (dB)	25.87	26.4	26.97
S_A-correction	-0.61	-0.32	-0.33

2.2.2 Sonar

'Juvel' is equipped with a high frequency sonar: Simrad SH 80 and a low frequency SP70. Neither of the sonars worked properly during the survey, and were not logged.

2.2.3 Acoustic moorings

An Aural hydrophone deployed last year for passive recording of whale sounds mounted together with an ASL echo sounder were successfully retrieved east of the 'Little canyon' at position S 60° 24.281 and W 045° 58.311.

The ASL mooring was not redeployed for a new year due to technical problems.

A NorTek Signature 55 combined echo sounder and Acoustic Doppler Current Profiler (ADCP; see details on deployment in Appendix) was successfully retrieved west of the 'Little canyon' at position S 60° 25.119 and W 046° 11.443. Preliminary replay of the data revealed that the mooring had been logging data until June, and likely had run out of battery. We changed the deployment settings to extend the data logging period and deployed the mooring at position S 60 21.429 and W 46 42.169.

2.3 Acoustic data analyses

2.3.1 Discrimination of targets

The method for target discrimination as described in the CCAMLR protocol requires data from the frequencies 38, 120 and 200 kHz and our data were collected at 38, 70 and 120 kHz. However, we used the idea that different targets have predictable frequency dependent volume backscattering strength (S_v; dB re m^{-1}) within a specified range of body lengths. Following this idea, targets which fall within a specific range of ΔS_v-values ($S_{v,120}$–$S_{v,38}$) will be identified as *E. superba*. The method was applied on sample bins of 514 m horizontal*5 m vertical resolution. The minimum and maximum ΔS_v-values defining the krill identification 'window' were calculated using the Stochastic Distorted Wave Born Approximation (SDWBA) package, SDWBApackage2010 (Conti and Demer 2006; SG-ASAM 2010; Calise and Skaret 2011), and was based on the krill length frequency distribution in 10 mm bins from the trawl samples where 95 % of the length frequency distribution was extracted from a cumulative probability density distribution (SG-ASAM 2010, SC-CAMLR 2005; Reiss et al. 2008). After the discrimination, the retained Nautical Area Scattering Coefficient (NASC)-values were averaged for each nautical mile.

2.3.2 Target strength prediction

The NASC were converted to biomass density (g m^{-2}) using the SDWBApackage2010 (Conti and Demer, 2006; SG-ASAM 2010; Calise and Skaret, 2011) according to the CCAMLR protocol. The model was parameterized according to Table 1, or if nothing else specified according to Calise and Skaret (2011).

The predicted target strengths were used to calculate weighted conversion factors (CF) from NASC-values to biomass density

$$CF = \left[\sum f_i \cdot W(TL_i)\right] / \left[\sum f_i \cdot \sigma(TL_i)\right]$$

where *f* is the frequency of a specific length group (*i*) and W(TL) is weight at total length, which was calculated following Hewitt et al. (2004):

$$W(g) = 2.236 \cdot 10^{-3} \cdot TL^{3.314}$$

σ(TL) is the backscattering cross-section at a specific total length and was calculated using the full SDWBA model.

2.3.3 Estimation of biomass

Based on the average biomass density for each nautical mile, a weighted biomass density for each transect line could be calculated and the sampling variance from the averages of each transect line according to Jolly and Hampton (1990).

3 Biological sampling

The survey design included trawl stations spaced ~20–25 nautical miles apart along the set parallel north-south oriented transect lines (Figure 1). The standard survey trawl used was 42 m long, with a 36 m^2 mouth opening, constructed of 7 mm (stretched) diamond shaped meshes from mouth to rear, or a 3 mm light opening (Figure 2). The trawl was towed using a 6 m wide steel beam with 200 kg weights at each lower wing tip and 1500 kg attached to the beam to ensure fast deployment to depth and the best possible geometric stability of the trawl during sampling (Figure 2).

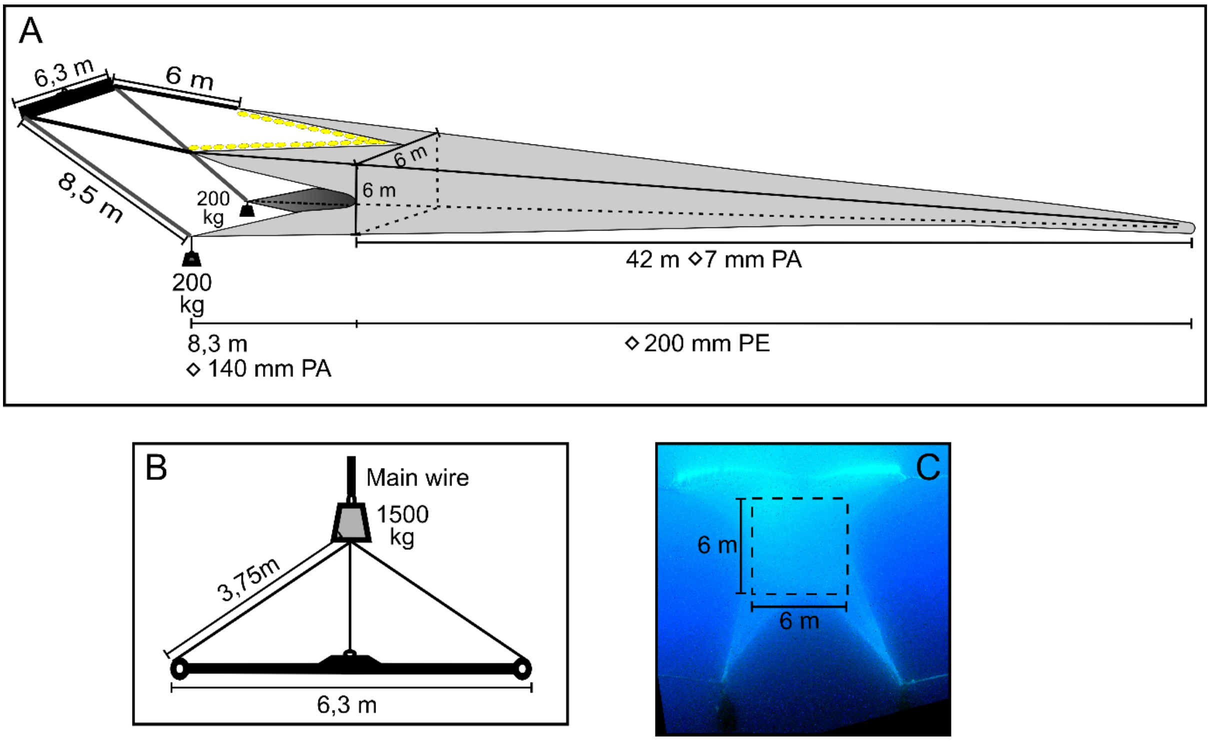

__Figure 2.__ The survey trawl with a 7 mm meshed inner net made of polyamide (PA) 140 mm meshed PA net in the mouth, and 200 mm meshed outer support net in polyethylene (PE) (A). Steel beam with rigging (B) and underwater image captured during towing showing the mouth opening (C). See also Figure 2. In Krafft et al. submitted.

At each station the trawl was lowered vertically from surface to ~200 m depth (or ~20 m above bottom if the water was < 200 m) and then hauled in at ~2.0 knots (includes both vessel and wire speed). When landed on the trawl deck, the cod end was opened and catch was removed. Thereby the towing rig was hung from a crane, and flushed on deck to wash out biological remains stuck in the net. The macro zooplankton and micronekton were sorted, identified to species or to the nearest possible taxonomic group, and weighed. For *E. superba*, the length of individual krill was measured (± 1 mm) from the anterior margin of the eye to the tip of telson excluding the setae, according to the "Discovery method" used in Marr (1962). Sex and maturity stages of *E. superba* were determined on fresh material using the classification methods outlined by Makorov and Denys (1981). In brief; in contrast to all other stages the juveniles had no visible sexual characteristics, males were divided into three sub adult stages: MIIA1, MIIA2 and MIIA3 and two adult stages: MIIIA and MIIIB, females were divided into one sub adult stage: FIIA and five adult stages: FIIIA, FIIIB, FIIIC, FIIID and FIIIE (see Krafft et al.2015 for further details).

3.1 Marine predator observations

Sightings for seabirds and marine mammals were carried out by one dedicated observer. Observations were made during daylight hours (0600–2100 local time); in total approximately 34 hours of observation were carried out. Observations were made along all survey transects and during transit between transects; no observations were made whilst trawling. Ship speed was 10 knots, with observations made from the bridge approximately 10 m above sea level.

Observations were made forward and to one side covering targets out towards the horizon, usually from the Forward Port Quarter, but on a few occasions from the Forward Starboard Quarter, depending upon weather conditions. Each recorded observation included the species and the number of individuals observed, the time (in UTC), the ship's position, the distance to the target at first sighting, and the relative angle from the vessel. For whales, seals and penguins the swim direction relative to the vessel was also recorded. Records were made using an in-house voice recording system which contains a microphone and a GPS connected to a laptop. The system records vessel position and time continuously at regular intervals, and a .wav sound-file is generated each time a sighting is read into an activated microphone.

Observations were carried out using the naked eye for spotting and through binoculars for identification. A range of texts were used to identify unknown species.

3.2 Krill behavioral experiment

To investigate krill behavior in relations to modifications in light conditions, a controlled experiment of live krill onboard was performed on individuals collected off the South Orkney Islands. The experimental tanks had chambers of different light levels to quantify preference of krill for a dark vs. light zone.

During the same time and area, a mooring equipped with sensors was constructed and anchored to the seafloor to record krill behavioral response to LED light in their natural environment. The rig contained an upward pointing powerful LED light source programmed to switch on and off every other hour, and an echo sounder storing data continuously for the presence and abundance of krill within the water column above the transducer.

These initial experiments were made to potentially stimulate further investigations including development of different design parameters.

4 Hydrographical sampling

A Seabird CTD sensor was mounted in an open metal frame for protection and welded on the trawl beam to obtain profiles of temperature and salinity during the trawl hauls. A fluorescence sensor was mounted on the same instrument.

5 Results

5.1 Acoustics

5.1.1 Acoustic survey estimates of krill distribution and biomass

The distribution of acoustic backscatter allocated to krill is shown if Figure 3. The highest NASC-values allocated to krill were observed in the easternmost transect line, further to the east than what is commonly observed previous years. Large biomass fluctuations are observed from year to year and this season the biomass of krill remained relatively dense in the concentrated area (Table 2).

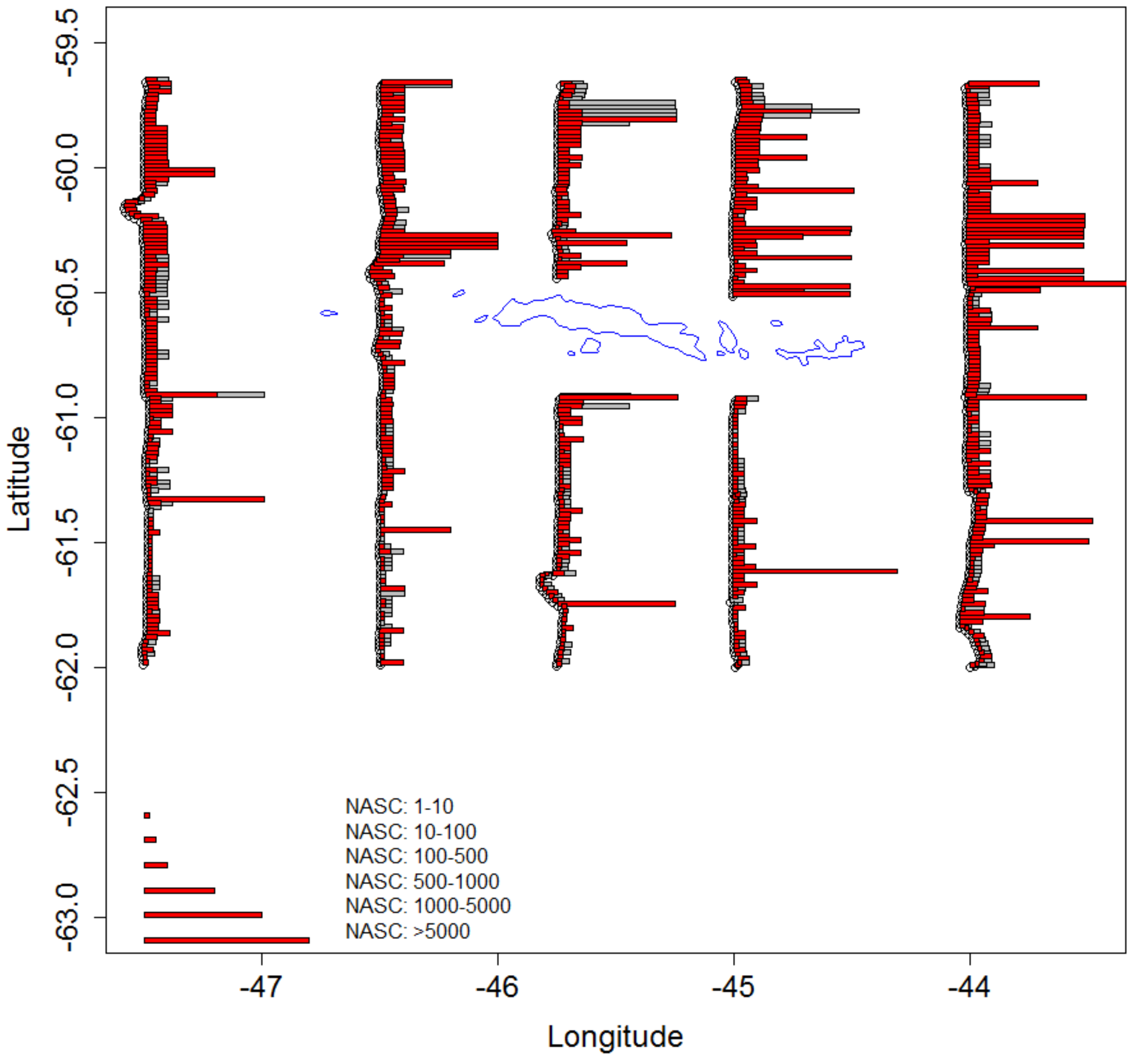

Figure 3. *Distribution of Nautical Area Scattering Coefficients (NASC; m^2/nmi^2) allocated to E. superba (red) and other targets (grey) from the 120 kHz recordings.*

Table 2. *Summary table of krill biomass estimation from all surveys, including the 2018 survey. The 'Subarea' refers to an area north of the islands which was defined in order to make comparisons between years despite incomplete survey coverage in some years. The years with full or near-full coverage were 2012, 2014, 2016, 2017 and 2018.*

	Entire covered area						Subarea							
Year	Freq	Density (g/m^2)	CV	**Freq**	**Density (g/m^2)**	**CV**	Freq	Density (g/m^2)	BM (mill. t)	CV	**Freq**	**Density (g/m^2)**	**BM (mill. t)**	**CV**
2011	38	69.31	12	**120**	**108.69**	**18**	38	121.79	3.29	17	**120**	**212.75**	**5.74**	**28**
2012	70	41.49	30	**120**	**86.93**	**32**	70	41.15	1.11	56	**120**	**94.79**	**2.56**	**66**
2013	38	118.19	26	**120**	**120.28**	**32**								
2014	38	73.69	38	**120**	**148.29**	**41**	38	143.02	3.86	42	**120**	**301.39**	**8.14**	**46**
2015	38	5.26	51	**70**	**7.10**	**49**	38	7.83	0.21	54	**70**	**10.42**	**0.28**	**51**
2016	38	57.10	53	**120**	**57.19**	**45**	38	9.4	0.25	33	**120**	**10.12**	**0.27**	**26**
2017	38	32.91	20	**120**	**42.23**	**26**	38	25.22	0.68	34	**120**	**30.71**	**0.83**	**51**
2018	38	59.00	22	**120**	**71.09**	**26**	38	91.16	2.46	31	**120**	**104.84**	**2.83**	**30**

5.2 Biological sampling

A total of 28 trawl stations was successfully completed during the survey (Figure 1). The total catch weight was dominated by salps accounting for 36.5% (and occurring at 7 stations), euphausids with 31.1% of the catch weight, cnidaria with 27.7%, fish with 1.5%, mysids with 1.4%, amphipods with 1.4% and 0.4% was other taxa (Figure 4).

Two species of krill was identified; *E. superba* and *Thysanoessa macrura* (Figure 5), with *E. superba* being most common (occurring at 27 and 23 stations, respectively) and with the highest catch volume of the two.

The average body length of *E. superba* was 45.4 ± 5.9 (SD) mm, and the range was 23–61 mm (Figure 6). The sexual maturation stage development composition was dominated by adult males with completely developed spermatophores (MIIB: 27.9%), and gravid females (maturation stages FIIIC 13.9% and FIIID 14.5%) (Table 3).

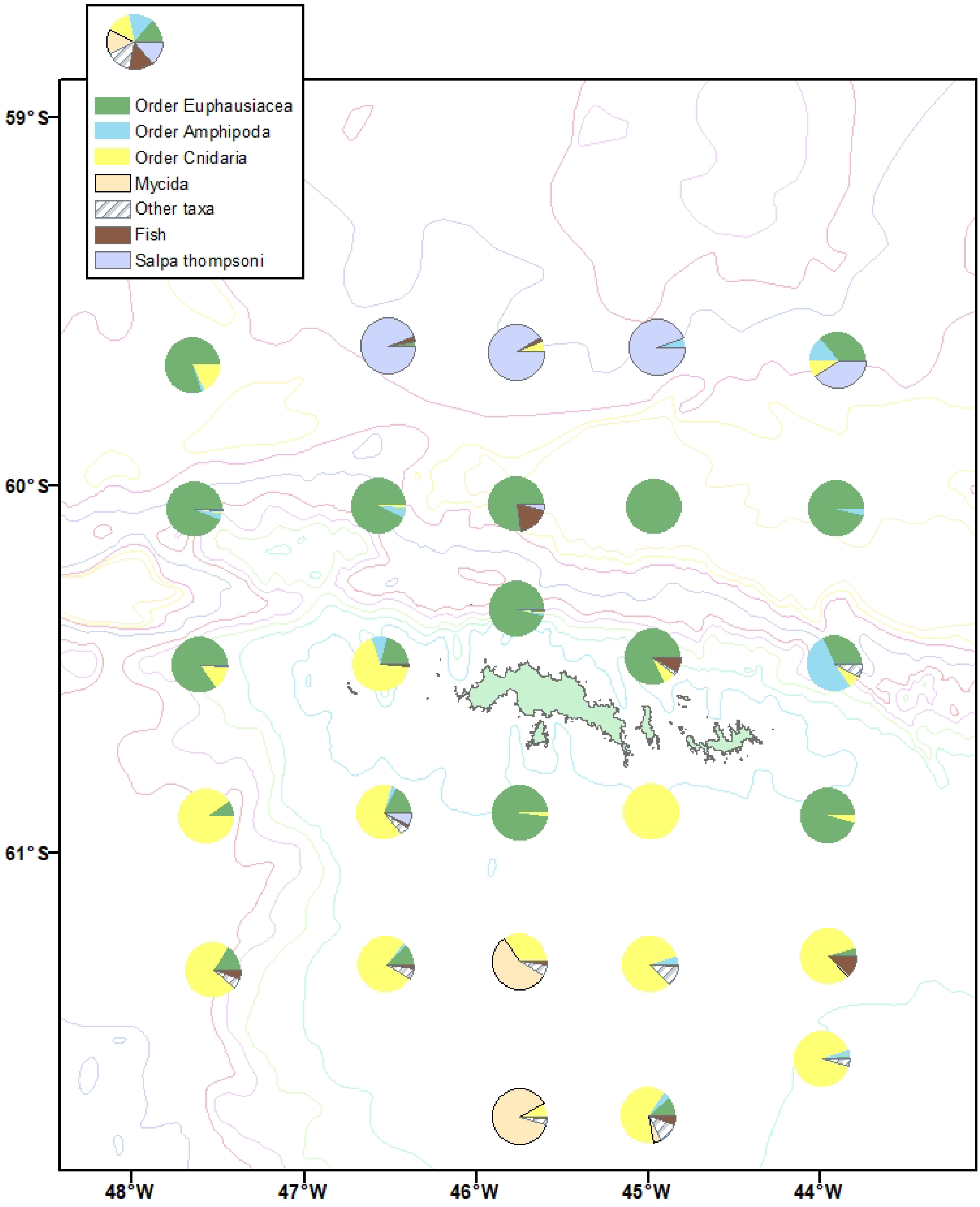

Figure 4. The most common taxa in terms of proportional catch weight.

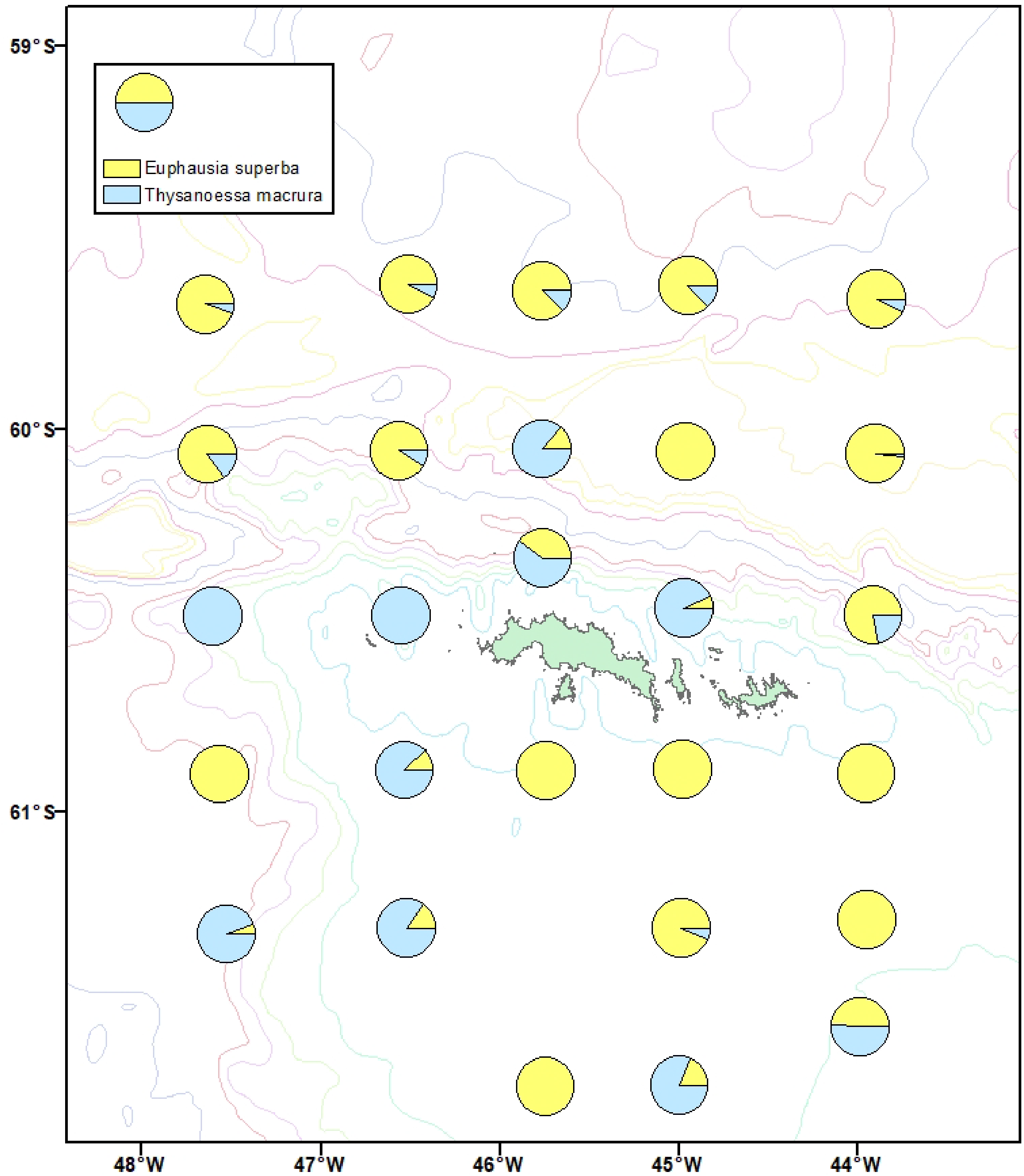

Figure 5. *Proportional distribution of the two krill species (E. superba and T. macrura) that occurred in the trawl catches during the survey in 2018.*

Table 3. *Number and proportions (%) of different sexual maturity stages of juvenile, male and female Antarctic krill caught in the South Orkney Islands area in the 2018 season.*

Stage	N	Proportion	Total length (mm)
Juvenile	45	3.4	32.0 ± 3.2
MIIA1	81	6.2	37.4 ± 2.3
MIIA2	78	5.9	42.0 ± 2.7
MIIA3	42	3.2	45.1 ± 2.4
MIIIA	45	3.4	47.6 ± 3.1
MIIB	368	27.9	49.0 ± 4.1
FIIB	84	6.4	38.4 ± 3.3
FIIIA	32	2.4	43.4 ± 4.0
FIIIB	120	9.1	45.2 ± 3.9
FIIIC	183	13.9	45.5 ± 3.6
FIIID	191	14.5	49.5 ± 4.7
FIIIE	48	3.6	46.6 ± 4.1
Total	**1317**		

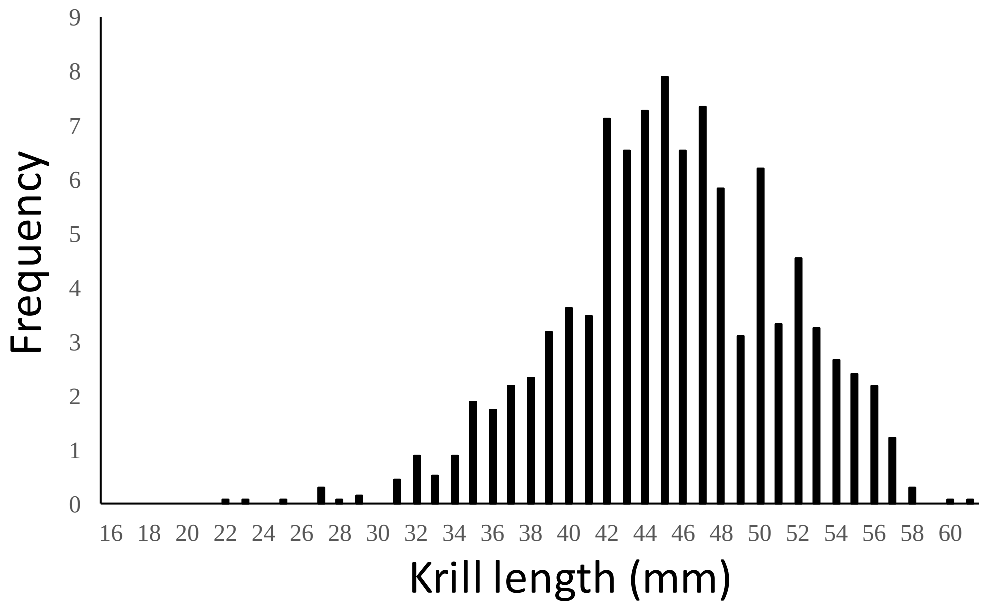

Figure 6. *Antarctic krill length histogram based on all samples from the 2018 survey combined.*

5.3 Hydrography

The hydrographical profiles from the survey area based on the trawl mounted ctd are shown in figure 7. There were marked thermoclines and haloclines in all casts around 50 m depth.

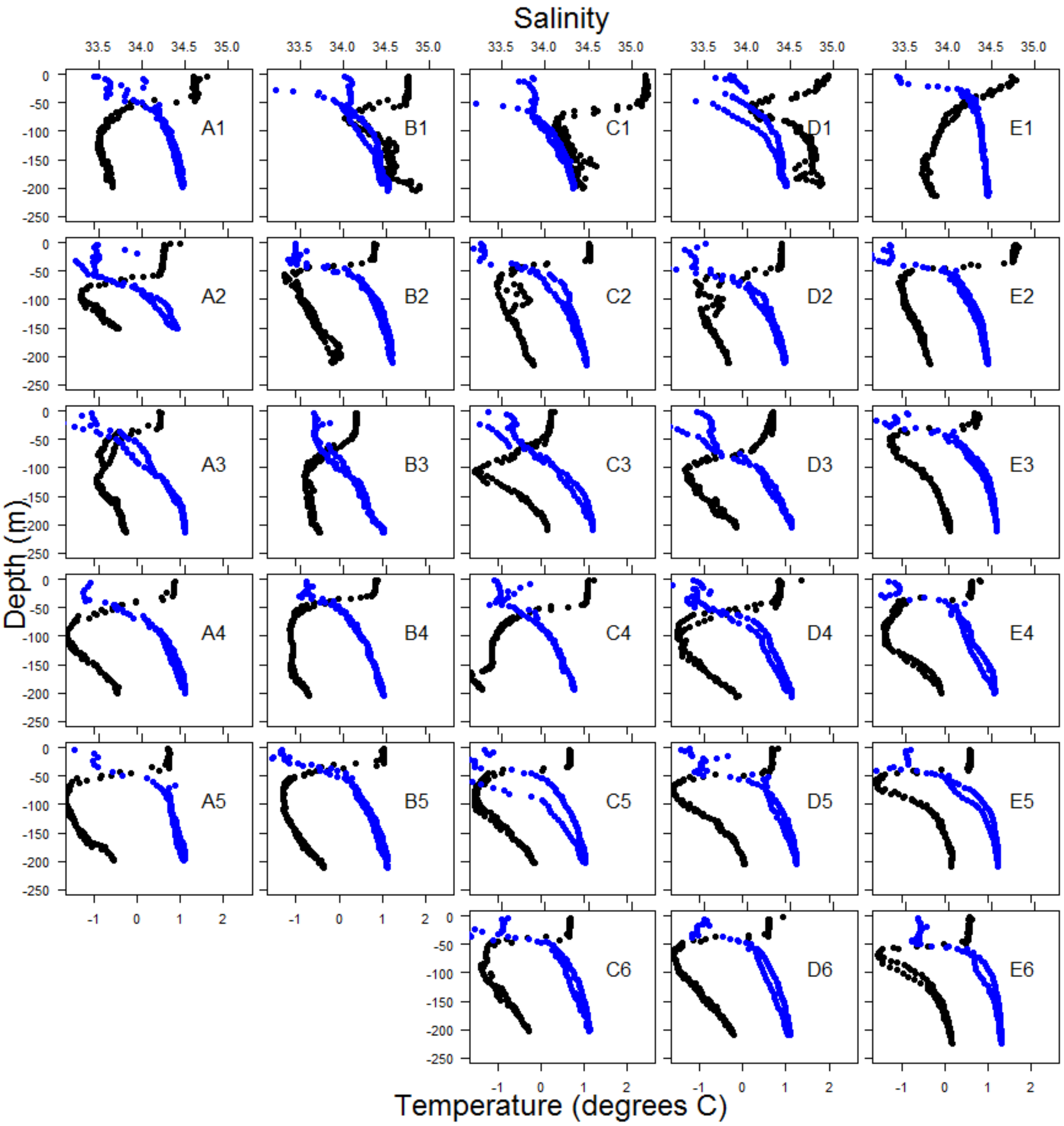

__Figure 7.__ Hydrographical profiles from the ctd-casts with temperature in black and salinity in blue.

5.4 Marine predator observations

The conditions for predator observing were average during most of the survey. There was swell and/or wind and also quite frequent periods of fog which limited the visual range. A total of 967 sightings of 1838 individuals covering 24 species of marine predators were done.

Notable observations were 94 whales, 511 chinstrap penguins (*Pygoscelis antarcticus*) and 128 Antarctic fur seals (*Arctocephalus gazella*) (Figure 8).

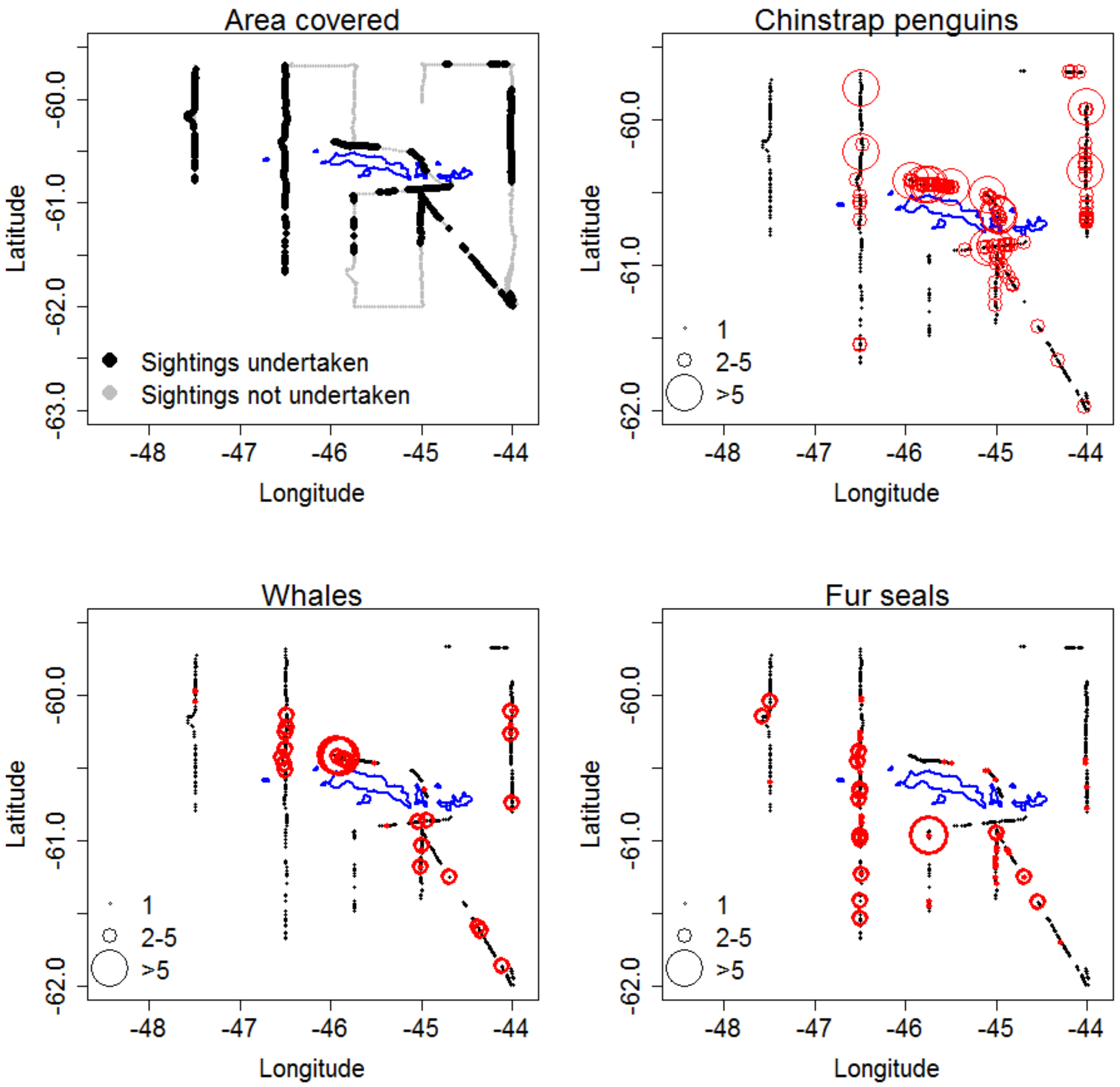

Figure 8. Overview of recorded sightings of chinstrap penguins (Pygoscelis antarcticus), whales (fin whales; Balaenoptera physalus and humpback whales; Megaptera novaeangliae) and fur seals (Arctocephalus gazella) during the survey.

6 Acknowledgements

We extend our gratitude to the Aker Biomarine AS for providing ‘Juvel’ and its crew to disposal for this research survey free of charge. We are most grateful to the captain, officers and crew on board ‘Juvel’ for all the help provided during the cruise.

7 References

Calise, L. and Skaret, G. 2011. Sensitivity investigation of the SDWBA Antarctic krill target strength model to fatness, material contrasts and orientation. CCAMLR Science, Vol. 18 (2011): 97–122

Conti, S.G. and D.A. Demer. 2006. Improved parameterization of the SDWBA for estimating krill target strength**.** ICES Journal of Marine Science, 63 (5): 928-935.

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

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

Jensen N, Nicoll R, Iversen SA (2010) The importance of obtaining annual biomass information in CCAMLR Sub-area 48.2 to inform management of the krill fishery. WG-EMM-10/9, 5 pp

Jolly GM, Hampton I (1990) A stratified, random-transect design for acoustic surveys of fish stocks. Canadian Journal of Fisheries and Aquatic Sciences 47: 1282–1291.

Krafft BA, Krag LA, Knutsen T, Skaret G, Jensen KHM, Krakstad JO, Larsen SH, Melle W, Iversen SA, Godø OR. Summer distribution and demography of Antarctic krill (*Euphausia superba*) (Dana, 1852) (Euphausiacea) at South Orkney Islands, 2011–2015. Journal of Crustacean Biology, submitted 2018.

Krafft BA, Skaret G, Knutsen T. 2015. An Antarctic krill (*Euphausia superba*) hotspot - population characteristics, abundance and vertical structure explored from a krill fishing vessel. Polar Biology 38:1687-1700 DOI 10.1007/s00300-015-1735-7

Makorov RR, Denys CJI (1981) Stages of sexual maturity of Euphausia superba. BIOMASS Handbook No. 11, pp 1-13

Marr J (1962) The natural history and geography of the Antarctic krill (*Euphausia superba* Dana). In: Discovery reports vol 32. National Institute of Oceanography, Cambridge University Press, Cambridge pp 33-464

Reiss C.S., A.M. Cossio, V. Loeb and D.A. Demer 2008. Variations in the biomass of Antarctic krill (Euphausia superba) around the South Shetland Islands, 1996-2006. ICES Journal of Marine Science. 65: 497-508.

SG-ASAM. 2010. Report of the fifth meeting of the subgroup on acoustic survey and analysis method. Cambridge, UK, 1 to 4 June 2010. Submitted for: *Report of the Twenty-ninth Meeting of the Scientific Committee (SC-CAMLR-XXIX/6).* CCAMLR, Hobart, Australia: 23 pp.

SC-CAMLR. 2005. Report of the First Meeting of the Subgroup on Acoustic Survey and Analysis Method (SG-ASAM). In: *Report of the Twenty-fourth Meeting of the Scientific Committee (SC-CAMLR-XXIV/BG/3)*, Annex 6. CCAMLR, Hobart, Australia: 564–585.

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