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Dedicated whale sighting vessels as a platform for krill and oceanographic research in the Indo-Pacific region of the Antarctic

Atsushi WADA*

Institute of Cetacean Research, 4–5 Toyomi-cho, Chuo-ku, Tokyo 104–0055, Japan

**Contact e-mail: wada@cetacean.jp*

ABSTRACT

The Institute of Cetacean Research has conducted research on the ecosystem in the Indo-Pacific sector of the Antarctic, as part of the JARPA, JARPAII and NEWREP-A whale research programs. As part of the ecosystem research, oceanographic and krill surveys have been carried out in a systematic manner using dedicated sighting surveys as platform. Krill are key species in the Antarctic ecosystem and changes in its abundance have effects on predators and the whole ecosystem. Changes in the oceanographic conditions will affect distribution and krill biomass and in turn the abundance and distribution of whales. Changes in oceanographic conditions might indicate effects of climate changes. This paper describes the technical aspects of the krill and oceanographic surveys conducted by the Institute of Cetacean Research from dedicated sighting vessels.

INTRODUCTION

The Institute of Cetacean Research (ICR) has conducted research on the ecosystem in the Indo-Pacific sector of the Antarctic in a systematic manner for a considerable number of austral summer seasons. The ecosystem research involved oceanographic and krill surveys, which were conducted as part of the JARPA (1987/88–2004/05), JARPAII (2005/06–2013/14) and NEWREP-A (2015/16–2018/19) whale research programs.

Oceanographic and krill research is important to understand changes in the Antarctic ecosystem. Krill are key species in the Antarctic ecosystem and changes in their abundance have effects on predators and the whole ecosystem. Changes in the oceanographic conditions will affect distribution and krill biomass and in turn the abundance and distribution of whales. Changes in oceanographic conditions might indicate effects of climate changes. Fujise and Pastene (2018) presented scientific evidence for historical and current changes in the Antarctic ecosystem. Historical changes were consistent with the 'krill surplus hypothesis' (Laws, 1977; 1985) while current changes were interpreted as the reverse of this hypothesis.

This paper describes the technical aspects of the krill and oceanographic surveys conducted by the ICR from dedicated sighting vessels. Oceanographic and krill survey plans and results have been presented and discussed at annual meetings of the International Whaling Commission Scientific Committee (IWC SC) as well the Convention for the Conservation of Antarctic Marine Living Resources Working Group on Ecosystem Monitoring and Management (CCAMLR-EMM). Surveys have been designed and conducted by following technical advice of experts from these meetings. Also this paper shows as an example, the results of the oceanographic and krill surveys conducted by NEWREP-A in the 2018/19 austral summer season.

DEDICATED SIGHTING VESSELS

Oceanographic and krill surveys were conducted from dedicated whale sighting surveys. A total of three research vessels were used during the NEWREP-A, which covered the IWC management Areas using zigzag tracklines (Figure 1, Table 1): *Yushin-Maru* No.2 (*YS2*; 747GT, Figure 2), *Yushin-Maru* No.3 (*YS3*; 742GT, Figure 3) and *Kaiyo-Maru* No.7 (*KY7*; 649GT, Figure 4). The transducers of Quantitative Echosounder (EK80; Simrad, Norway) were hull-mounted at a depth of 4.3 m below the sea surface in the case of *YS2* and *YS3*. The transducers of Quantitative Echosounder (EK60; Simrad, Norway) were hull-mounted at a depth of 4.7 m below the sea surface in the case of *KY7*. The electrical winch (TS-F2, Tsurumi-Seiki Co., Ltd., Japan, Figure 5) was set at the right side deck in the case of *YS2* and *YS3*.

INSTRUMENTS USED FOR KRILL SURVEY

All three survey vessels were mounted with Quantitative Echosounders for acoustic data recording. These data are

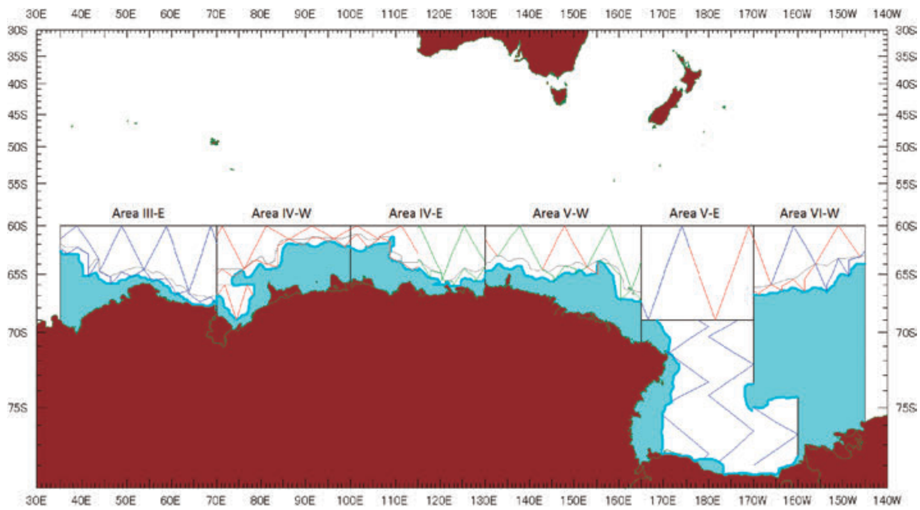

Figure 1. Research area and tracklines. Blue line: surveyed trackline of *Yushin-Maru* No. 2, Green line: surveyed trackline of *Yushin-Maru* No.3, Red line: surveyed trackline of *Kaiyo-Maru* No.7, Gray line: boundary between northern and southern research area, Turquoise line: ice edge, Brown: Antarctic continent.

Table 1

Research area and vessels covered by NEWREP-A. *YS2*: *Yushin-Maru* No. 2, *YS3*: *Yushin-Maru* No. 3, *KY7*: *Kaiyo-Maru* No. 7.

Area	Season			
	2015/16	2016/17	2017/18	2018/19
III-NE				*YS2*
III-SE				*YS2*
IV-NW				*KY7*
IV-SW				*KY7*
Prydz Bay				*KY7*
IV-NE	*YS3*			*KY7*
IV-SE	*YS3*			*KY7*
V-NW		*YS3, KY7*		
V-SW		*YS3, KY7*		
V-NE			*YS2, KY7*	
V-SE			*YS2*	
VI-NW			*YS2, KY7*	
VI-SW			*YS2, KY7*	
VI-SW*			*YS2*	

*Southern of 69°S

Figure 2. *Yushin-Maru* No.2 (*YS2*).

Figure 3. *Yushin-Maru* No.3 (*YS3*).

used to estimate distribution and biomass of krill in the research area. Such estimate requires information on krill species and krill body length, which is obtained from net sampling. Two types of net sampling were used, Isaacs-Kidd Midwater Trawl (IKMT) and small ring net sampling.

The IKMT sampling was carried out by *KY7* while the small ring net was used by *YS2* and *YS3*. Due to its small size, the small ring net cannot be used for obtaining representative information of some quantitative traits (e.g. number of individuals and length frequency distribution of krill in the area) but the qualitative information (e.g. the species occurring in the echo-signs) can be obtained.

Quantitative Echosounder

All three vessels steamed on the predetermined tracklines and acoustic data were recorded continuously. The usual navigation speed of *YS2* and *YS3* was approxi-

Figure 4. *Kaiyo-Maru* No.7 (*KY7*).

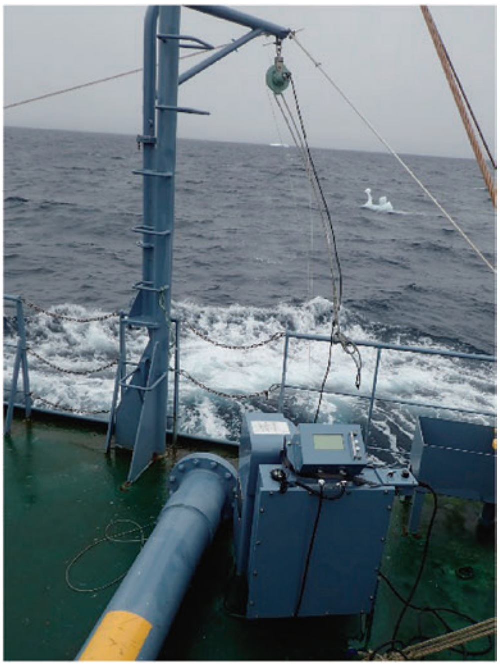

Figure 5. The electrical winch at *Yushin-Maru* No. 3.

mately 11.5 knots. The speed of *KY7* was 11.0 knots. All Quantitative Echosounders operated with frequencies at 38 kHz, 120 kHz and 200 kHz. Maximum data recording depth was set at 500 m.

Standard calibration of Quantitative Echosounders was made using a standard method (Demer *et al.*, 2015) in the vicinity of Japan and also at the research area before starting the research. This was done for every survey to determine the likely effective acoustic sampling range and the potential for detecting krill for multiple frequencies over the required survey depth.

Also calibration between EK80 (*YS2*, *YS3*) and EK60 (*KY7*) Quantitative Echosounders was conducted when *YS3*, *YS2* and *KY7* passed nearby following the procedure of Simmonds and MacLennan (2005) (Figure 6).

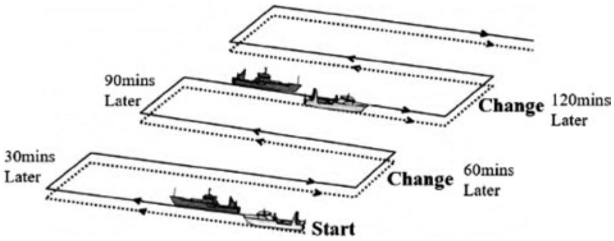

Figure 6. Procedure for the calibration of EK80 and EK60 Quantitative Echosounders (Based on Simmonds and MacLennan, 2005).

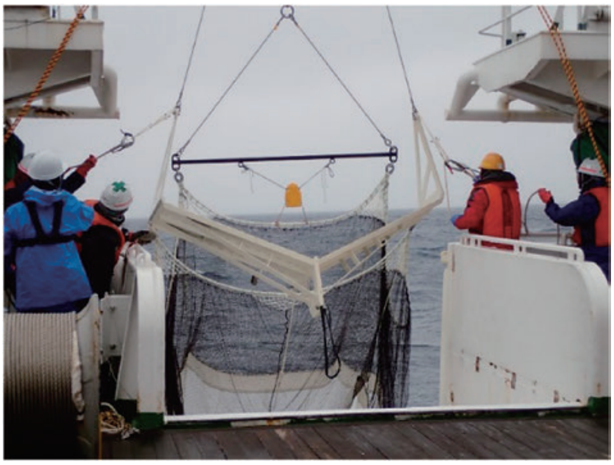

Figure 7. IKMT sampling net at the *Kaiyo-Maru* No. 7.

IKMT sampling

As noted above, the *KY7* was equipped with an IKMT designed by Nippon-Kaiyo Co., Ltd. Japan (Figure 7). The purpose of IKMT sampling was the collection of qualitative and quantitative information for krill (e.g. determination of the species occurring in echo signs and representative numbers and krill length frequencies). The sampling was conducted during day time. The IKMT was 3.66 m in mouth diameter and 18.43 m length. For comparative purposes with the small ring net, 0.5 mm mesh size was used for IKMT.

Data Storage Tag (DST) was installed at the mouth of the IKMT to record actual depth of the net. On average, it took approximately 11 minutes per haul excluding time for setting. The target depth of net sampling was set based on depth of echo sign but the maximum depth was 200 m. The depth of the mouth was monitored at the bridge by PI sensor (PI32; Simrad, Norway). Towing speed of IKMT was 1.0 m/s.

Small ring net sampling

All three vessels were equipped with a small ring net that had a mouth opening of 1.0 m across, and 2.4 m or 3.0 m length. Mesh size was 0.5, 1.5 or 4.5 mm (Nippon-Kaiyo Co., Ltd. Japan, Rigosha & Co., Ltd. Japan, Figure 8) (Trathan *et al.*, 2001). At the time of the sampling the vessels stopped their engines.

The target depth of net sampling followed echo backscattering to a maximum of 200 m. If a Light Emitting Diode (LED) and digital compact camera were attached to the net, the maximum depth was switched to 100 m because of their pressure capacity. The depth of the mouth was estimated visually from the angel of the wire with a protractor. The accurate depth of the mouth was confirmed by DST record in the laboratory. If DST were not used, the accurate depth of the mouth was checked by PI sensor at the field. Hauling speed of the net was approximately 1.0 m/s depending on sea state.

The small ring net sampling was conducted to identify the species targeted by echo signs. Notably, the purpose of using this net in *KY7*, was to check efficiency of the small ring net by comparing the samples with those obtained by IKMT. If the small ring net samples collected sufficient amount of samples to examine length frequency of krill and the composition of plankton samples was similar to those collected by IKMT, the result of the small ring net are useful. The small ring net hauls were carried out as in *YS2* and *YS3*, but were only conducted where IKMT collected swarms of krill.

Sample treatment

All plankton samples were kept in bottles with 10% formalin and/or frozen at −20°C for further analysis in the laboratory. Preliminary standard measurements (AT) of krill sampled, were carried out onboard the vessels. The AT is measured from the front of the eye to the tip of the telson, the thin, tapered triangular plate at the end of the abdomen (CCAMLR, 2011, Figure 9).

Recording depth of net

A Data Storage Tag (DST Centi-ex, Star Oddi Co., Ltd., Iceland, Figure 10) was put at the mouth of the small ring nets and IKMT for recording temperature and depth at one second intervals. Temperature Depth Recorders (TDR, AL1, Ishida Engineering, Japan, Figure 11) and PI sensors were used as an alternative to DST in 2015/16 and 2017/18 NEWREP-A, respectively. The TDR was put in mouth of the net for recording temperature and hydraulic pressure. The PI sensor was put on the small ring net

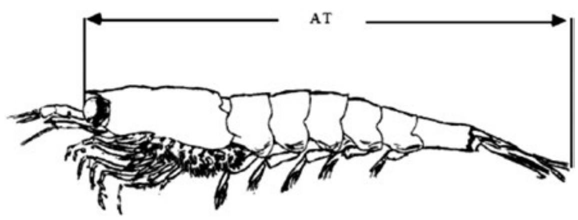

Figure 9. Measurement of total body length (AT) of krill (CCAMLR, 2011).

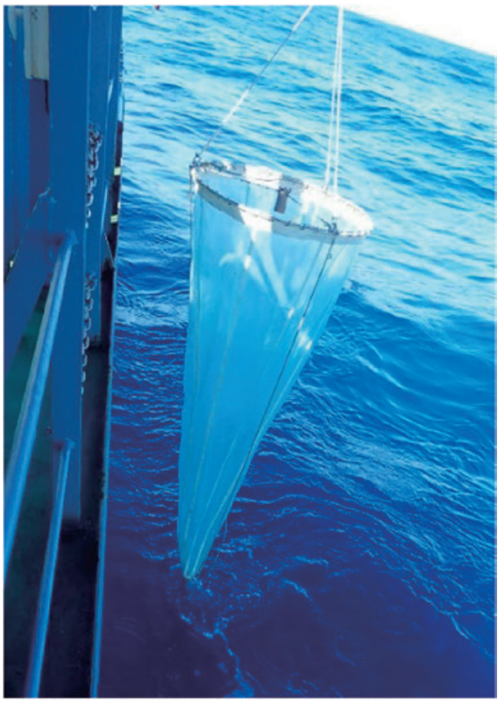

Figure 8. Small ring net at the *Yushin-Maru* No. 2.

Figure 10. The Data Storage Tag (DST).

Figure 11. The Temperature Depth Recorder (TDR).

Figure 12. LED with camera used for attracting krill in the small sampling net.

and depth read from the display directly at one minute intervals.

Attracting krill

In some surveys small net sampling was conducted with LED and a movie recorded the appearance of the mouth. Almost in all net sampling, a maximum 3,000 lumen LED (FIX NEO 3000 DX, Fisheye Co., Ltd., Japan), digital compact camera (TG-4 Tough, Olympus Co., Ltd., Japan) and housing system (Nauticam TG3, Fisheye Co., Ltd., Japan) (Figure 12) was put in mouth of net (Wiebe *et al.*, 2004). The lighting system was not used after the 2015/16 NEWREP-A following recommendations by CCAMLR specialists (CCAMLR, 2016).

INSTRUMENTS USED FOR OCEANOGRAPHIC SURVEYS

Oceanographic observations were based on Japan Meteorological Agency (1999) standards and conducted in parallel with krill surveys.

CTD casting

Hydraulic pressure, temperature, salinity, chlorophyll-*a* and dissolved oxygen were recorded from sea surface to 500 m depth using Conductivity-Temperature-Depth profiler (CTD). The CTD SBE 19 plus V2 SeaCAT (Sea-Bird Scientific Inc., USA, Figure 13) was used by the *YS2* and *YS3*, and the SBE 19 plus SeaCAT (Sea-Bird Scientific Inc., USA) was used by the *KY7*. The instruments were descended using an electrical winch with diameter of 3 mm and an overall length of 1,000 m wire. Normally CTD was descended to 500 m. The data from the CTD was uploaded for conversion by following the manual. All CTD were calibrated before every cruise by Sea-Bird Scientific Inc.

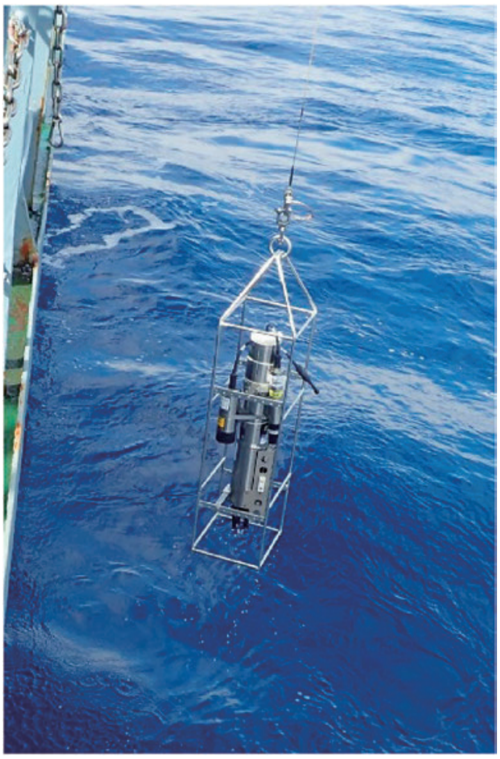

Figure 13. CTD at *Yushin-Maru* No. 2.

Seawater sampling

The seawater sampling was carried out for calibrating the CTD sensors. Niskin water sampling bottles Model-1010 1.2L (General Oceanics, Inc., USA, Figure 14) were used by *YS2* and *YS3* and Model-1010 1.7L (General Oceanics, Inc., USA, Figure 15) was used by *KY7*. The bottles were dropped to depths from 0 to 200 m and sampling was conducted every 20 m. Depth information of sampling bottles was based on the angle of the wire while operating. Accurate depths of sampling bottle were recorded at the laboratory from the DST or PI sensor.

The seawater was kept in freezers for subsequent analysis in the laboratory. The sea water was kept in two bottles. One was a 250 mL clarity seawater bottle (WOCE type 5419-C, Rigosha & Co. Ltd., Japan) for salinity calibration, which was stored at 4°C. The other bottle was for chlorophyll-*a* calibration. 118 mL of seawater from the bottles was filtrated (Whatman 233303 GF/F 25 mm, GE Healthcare, USA) (Figure 16). The filter paper was kept in 8 mL centrifugal tubes (60.452, Sarstedt AG & Co., Germany) filled with dimethylformamide. The tubes were stocked in freezer about −20°C (Saito, 2007). After the cruises, salinity was measured by Autosal Salinometer OSIL 8400B (Ocean Scientific International Ltd, UK) and chlorophyll-*a* was measured by TURNER 10AU Field and Laboratory Fluorometer (Turner Designs, Inc., USA).

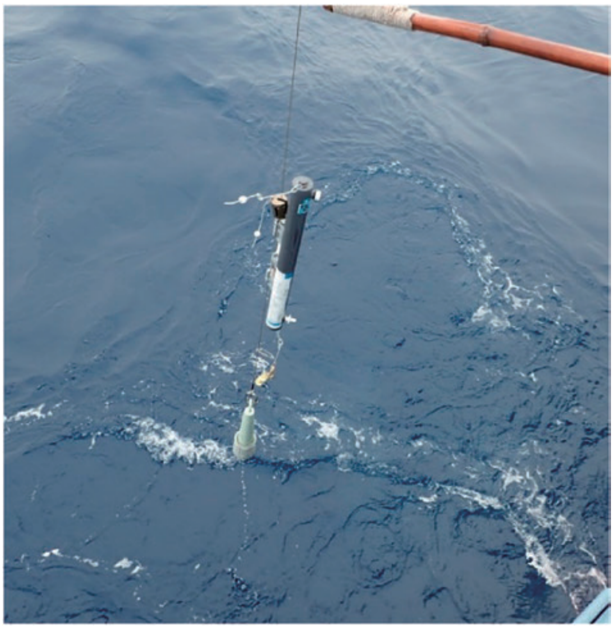

Figure 14. Niskin water sampling bottle at *Yushin-Maru* No. 2.

Figure 15. Niskin water sampling bottle at *Kaiyo-Maru* No. 7.

Figure 16. Filtrating seawater with filter paper.

HOW THE KRILL AND OCEANOGRAPHIC SURVEYS ARE CONDUCTED FROM A WHALE SIGHTING VESSEL?

The trackline was designed for the main purpose of abundance estimates of large whales based on the DISTANCE sampling (Buckland *et al.*, 2015). It followed the accepted guidelines by the IWC SC for the International Decade for Cetacean Research/Southern Ocean Whale and Ecosystem Research (IDCR/SOWER) cruises (Matsuoka *et al.*, 2003). The trackline consisted of a zigzag course changing direction at each 5°00′ longitudinal degree intervals in the northern stratum and at 2°30′ longitudinal degree intervals in the southern stratum. The trackline in the Ross Sea was set zigzag in north and south to westward or eastward. The zigzag course changed direction at 1°30′ latitudinal degree intervals. Also the trackline in the Prydz Bay changed direction in northward or southward at 2°30′ longitudinal degree intervals. A randomized start point was determined based on the IWC SC guidelines (IWC, 2012).

The sighting surveys were conducted during the daytime from an hour after sunrise to an hour before sunset. The vessel would move through the tracklines at a speed of 11.0–11.5 knots. The survey stopped when the sea conditions and weather were not appropriate for sighting activities. When the conditions improved, the vessel restarted the survey from the same position on the trackline. Three researchers participated onboard the vessels, two in charge of the sighting survey and one in charge of the krill and oceanographic surveys.

Details of the sighting survey procedures used by the ICR can be found in Hakamada and Matsuoka (2017).

Krill survey

The Quantitative Echosounder data were recorded continuously while vessels steamed on the predetermined tracklines, day and night. Only the acoustic data obtained when the vessels were on the trackline are used for krill abundance estimates.

All net sampling was conducted following the echo sign by the Quantitative Echosounder (Figure 17). When the researcher confirmed a swarm of krill and decided to tow the net, the sighting survey was stopped and preparation for net sampling was made as soon as possible. In principle, net sampling was conducted once a day in the 2015/16 and 2016/17 NEWREP-A. In order to increase the number of samples, net sampling was conducted after each confirmation of echo signs in the 2017/18 and 2018/19 NEWREP-A.

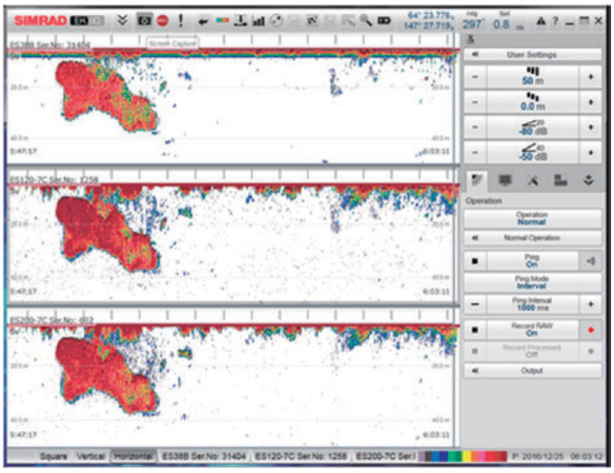

Figure 17. Echo sign of Antarctic krill by the EK80 of *Yushin-Maru* No. 3.

During the IKMT sampling, the vessel steamed approximately at 2.0 knots. In the case of small ring net sampling, the vessels stopped their engines when reconfirming echo sign. Both sampling was conducted with careful confirmation of krill swarm location by monitoring of the Quantitative Echosounder. When the net sampling was completed, the vessel re-started sighting surveys from the same position on the trackline that had stopped for the sampling. Preliminary analyses of the sample were carried out immediately after sampling.

Oceanographic survey

It was planned that oceanographic observations using CTD casting would cover the whole area, and for this reason the geographical position of the CTD casting stations would not necessarily coincide with the position of the net sampling. The CTD casting stations were positioned at approximately 60 n.miles on the trackline. The vessels stopped their engines when they arrived at the CTD casting station. Once observations were completed, they re-started the sighting surveys from the same position on the tracklines where the vessels had stopped their engines.

To calibrate the CTD sensors, the stations for seawater sampling were the same as some CTD casting station. Each station was positioned approximately within a radius of 120 n.miles in entire research area for covering the entire area.

Net sampling, CTD casting and seawater sampling were conducted during day time and smooth sea states.

RESULTS OF THE 2018/19 KRILL AND OCEANOGRAPHIC SURVEY

As an example, this section shows the results of the 2018/19 NEWREP-A in management Areas III-E and IV. The surveys were conducted by the research vessels *YS2* and *KY7*.

Quantitative Echosounder

Calibrations of Quantitative Echosounders were made on 30 October 2018 by *YS2* and on 7 November 2018 by *KY7* in the vicinity of Japan before departure for the Antarctic. During the calibrations, the vessel's engines were stopped for anchoring at sea bottom 37 m for *YS2* and 48 m for *KY7*. Calibrations in the survey area were made on 13 December 2018 by *YS2* and on 6 December 2018 by *KY7* before starting the survey on the tracklines. During the calibrations, the vessel's engines were stopped and the drifting speed was approximate 0.7 knots because anchoring at that depth could not be achieved in the Antarctic. The data from the Quantitative Echosounders was recorded according to setting of calibration in Antarctic.

The Quantitative Echosounders calibration (EK80 in *YS2* and EK60 in *KY7)* was conducted on 12 November 2018 in Japanese coastal areas. The methodology of Simmonds and MacLennan (2005) was followed. The Quantitative Echosounder data were recorded by *YS2* and *KY7* moving in formation with one in the lead and the another about 400 m astern, far enough to the side to be clear of the leader vessel's wake. The two vessels took the lead in turns and exchanged positions at the end of each transect. Both research vessels recorded Quantitative Echosounders data while shifting the leaders every 30 minutes four times for two hours. As a result, calibrations between EK80 and EK60 were recorded shallow over 200 m sea bottom backscattering constantly by all three frequencies, 38 kHz, 120 kHz and 200 kHz.

Table 2 shows a summary of the total effort spent on the Quantitative Echosounder survey. This survey was conducted for a total of 7,195 n.miles along the tracklines (3,365 n.miles in Area III-E, 2,267 n.miles in Area IV-W, 509 n.miles in Prydz Bay and 1,055 n.miles in Area IV-E).

IKMT sampling

IKMT sampling was conducted at a total of 22 stations by *KY7* (10 stations in Area IV-W, seven stations in the Prydz Bay and five stations in Area IV-E, Tables 2, 3 and Figure 18). Logistical considerations were also taken into account to decide whether to proceed with net sampling such as the sea state, sea ice as well as other survey priorities.

Small ring net sampling

The small ring net sampling was conducted at a total of 54

Table 2
Research item and summary in the 2018/19 NEWREP-A.

Area	Quantitative Echosounder		IKMT stations	Small ring net stations	CTD casting stations	Seawater sampling stations	DST stations
	Days	n.miles					
III-NE	39	2,175	—	17	42	5	17
III-SE	32	1,191	—	28	27	2	28
IV-NW	15	1,254	3	0	19	3	3
IV-SW	17	1,013	7	6	23	2	14
Prydz Bay	6	509	7	1	11	2	7
IV-NE	8	587	1	2	8	1	3
IV-SE	9	468	4	0	14	1	4
Total	72*	7,195	22	54	144	16	76

*The survey was conducted some areas at same day

Table 3
Summary of IKMT sampling in 2018/19NEWREP-A.

Area	Antarctic krill		Ice krill		Bigeye krill		*Euphausiids*		Copepoda		Other Zooplankton		Fish	
	Stations	%	Stations	%	Stations	%	Stations	%	Stations	%	Stations	%	Stations	%
IV-NW	2	67	0	0	1	33	0	0	0	0	0	0	1	33
IV-SW	6	86	0	0	0	0	1	14	0	0	2	29	0	0
Prydz Bay	6	86	1	14	0	0	0	0	1	14	1	14	1	14
IV-NE	0	0	0	0	0	0	0	0	1	100	1	100	0	0
IV-SE	2	50	0	0	0	0	3	75	1	25	2	50	0	0
Total	16	73	1	5	1	5	4	18	3	14	6	27	2	9

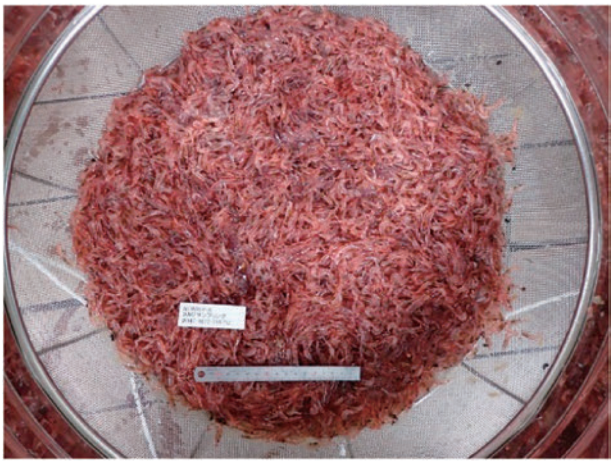

Figure 18. Antarctic krill sample of IKMT.

stations by *YS2* and *KY7* (45 stations in Area III-E, six stations in Area IV-W, one station in the Prydz Bay and two stations in Area IV-E, Tables 2, 4 and Figure 19). Because of weather, sea ice conditions or survey priority reasons, some net sampling stations were skipped. Calibration of the flow meters was conducted on 10 December 2018 by *YS2* and on 6 December 2018 and 30 January 2019 by *KY7* respectively.

Sample contents of the net

A total of 11 species, including three euphausiid species: Antarctic krill (Figure 20), ice krill *E. crystallorophias* (Figure 21) and bigeye krill *Thysanoessa macrura* (Figure 22) and fish (Figure 23 and 24), were identified in the 73 net sampling contents. Several other species, *Hydromedusae*, *Siphonophorae*, *Polychaeta*, *Pteropoda*, *Copepoda* (Figure 25), *Amphipoda* and *Chaetognatha* were confirmed by small ring net sampling and IKMT sampling. There were no contents at three net sampling stations.

Distribution of krill

Tables 3 and 4 show the summary of frequencies of occurrence of krill species and *Copepoda* sampled by the IKMT and small ring nets, respectively. Antarctic krill was sampled at 48 stations in entire of survey area. Distribution of surface water temperature was in the range of −1.7°C to 1.9°C. The Antarctic krill were sampled at depths

Table 4
Summary of small ring net sampling in 2018/19NEWREP-A.

Area	Antarctic krill		Ice krill		Bigeye krill		*Euphausiids*		Copepoda		Other Zooplankton	
	Stations	%	Stations	%	Stations	%	Stations	%	Stations	%	Stations	%
III-NE	7	41	0	0	6	35	0	0	12	71	16	94
III-SE	21	75	0	0	3	11	0	0	18	64	20	71
IV-NW	—	—	—	—	—	—	—	—	—	—	—	—
IV-SW	4	67	0	0	0	0	0	0	0	0	1	17
Prydz Bay	0	0	0	0	0	0	0	0	0	0	1	100
IV-NE	0	0	0	0	0	0	0	0	1	50	1	50
IV-SE	—	—	—	—	—	—	—	—	—	—	—	—
Total	32	59	0	0	9	17	0	0	31	57	39	72

Figure 19. Antarctic krill sample of small ring net.

Figure 20. Antarctic krill.

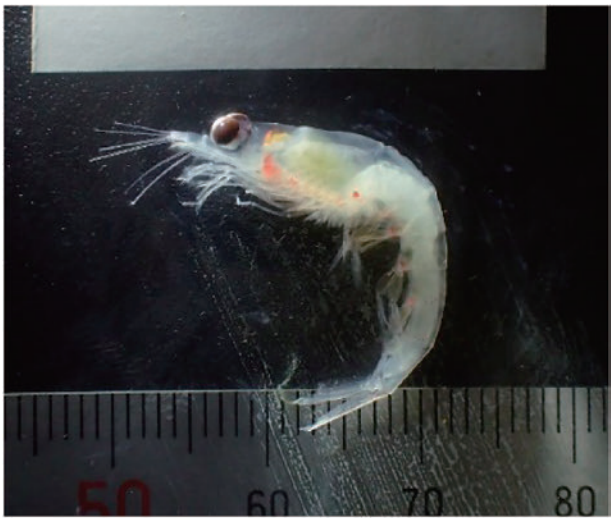

Figure 21. Ice krill.

Figure 22. Bigeye krill.

of 19 m to 146 m, depth of sea bottom range was 178 m to 5,240 m. The range of body length was from 12 mm to 59 mm. The incubating Antarctic krill was sampled at two stations in Area III-SE. Ice krill was sampled at a station in the Prydz Bay, distribution of surface water temperature was 1.6°C. They were sampled at depths of 130 m, depth of sea bottom was 670 m. Bigeye krill were sampled at ten stations, distribution of surface water temperature

Figure 23. Antarctic silverfish (*Pleuragramma antarcticum*).

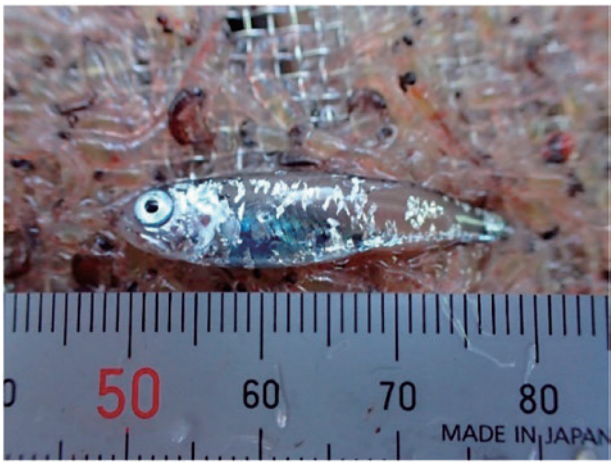

Figure 24. *Myctophidae.*

Figure 25. *Copepoda.*

was in the range of −1.4°C to 1.0°C. They were sampled at depths of 35 m to 146 m, depth of sea bottom range was 2,100 m to 5,240 m. The range of body length was from 10 mm to 25 mm.

Comparison of IKMT and small ring net

Simultaneous samplings with the small ring net and IKMT were conducted at seven stations by *KY7*. In three cases, Antarctic krill was sampled by both IKMT and small ring net. However, for the other four cases, the results from both nets were not consistent. In the 2016/17 and 2017/18 NEWREP-A, a total of seven cases of simultaneous sampling occurred, two cases were consistent for both nets (Wada *et al.* 2017; 2018). These results indicate that it is difficult to collect representative krill samples by the small ring net. However, the small ring net can contribute to obtaining qualitative information on the distribution of krill species and it requires less time in comparison to IKMT sampling.

Oceanographic observation

The oceanographic observation by CTD casting was conducted at 144 stations by *YS2* and *KY7* (69 stations in Area III-E, 42 stations in Area IV-W, 11 stations in the Prydz Bay and 22 stations in Area IV-E, Table 2). The seawater sampling was conducted at 16 stations at the same locality where CTD castings were taken. Seven stations in Area III-E and five stations in Area IV-W, two stations in the Prydz Bay and two stations in Area IV-E were sampled (Table 2). A total of 176 seawater samples were taken then kept in clear bottles for salinity calibration. For chlorophyll-*a* calibration samples were filtered and stored with dimethylformamide.

ANALYSES OF DATA

The main objective of krill and oceanographic surveys was to estimate the abundance of Antarctic krill acoustically, and to obtain the length frequency distribution and maturity stage of Antarctic krill in the survey area.

Quantitative Echosounder data is used for estimating krill abundance. The software Echoview 9 (Echoview Software Pty. Ltd., Australia) is used for calculating backscattering of krill after noise removal. Estimate value of krill abundance is obtained from this backscattering in each research area. This estimate requires identification of krill species and body length obtained by the IKMT sampling and small net sampling.

The oceanographic data is used for identifying structure of ocean currents likely Upper Circumpolar Deep Water, Lower Circumpolar Deep Water and Shelf Water based on CTD data. These currents are assumed in relation to the distribution of krill and predators.

The analyses are being conducted by the ICR and several external research organizations.

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