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INTERNATIONAL WHALING COMMISSION

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ABSTRACT

The krill and oceanographic surveys were conducted in the Antarctic area V-E and VI-W during the 2017/18 austral summer season as part of third dedicated sighting survey of the New Scientific Whale Research Program in the Antarctic Ocean (NEWREP-A). These surveys, which were conducted by two research vessels Yushin Maru No. 2 (YS2) and Kaiyo Maru No. 7 (KY7), are associated with the main objective II of NEWREP-A. The krill survey was conducted along the zig-zag tracklines designed for the whale sighting survey. Acoustic data using quantitative echosounders EK80 (YS2) and EK60 (KY7) were recorded continuously for total 73 days and 6,608 n.miles. Net sampling using a small ring net (YS2 and KY7) and an Issak-Kid Midwater Trawl (IKMT) (KY7) was carried out to identify species and size composition of plankton echo signs at 47 stations and 11 stations, respectively. Oceanographic observations were also conducted at 112 stations using a Conductivity-Temperature-Depth profiler (CTD) and seawater sampling occurred at 16 stations. Calibration among EK80 and EK60 quantitative echosounders, and simultaneous samplings between small ring net and IKMT were also conducted. Krill and oceanographic data are currently being examined, and results will be reported in related CCAMLR working group and/or the mid-term review of NEWREP-A.

KEYWORDS: EUPHAUSIIDS; ACOUSTICS; NET SAMPLING; OCEANOGRAPHY; ANTARCTIC

INTRODUCTION

Krill is a dominant prey for many predators in the Antarctic Ocean, and the Antarctic krill (*Euphausia superba*), ice krill (*E. crystallorophias*) and bigeye krill (*Thysanoessa macrura*) are all important prey species for the Antarctic minke whale (*Balaenoptela bonaerensis*) and other baleen whale species. Since the Antarctic minke whales highly dependent on those krill species, quantitative information of krill on a long-term basis is important for understanding ecological changes involving the Antarctic minke whales.

NEWREP-A includes surveys for krill abundance and distribution, which is relevant to the main objective II. Annual krill and oceanographic surveys were planned along with dedicated whale sighting surveys, aimed to obtain a relative index of abundance among years (GOJ, 2015).

The krill and oceanographic survey plan for 2017/18 was presented and discussed at the 2017 meeting of the International Whaling Commission Scientific Committee (IWC SC) (Hakamada *et al*., 2017, IWC, 2017). The plan was also discussed separately with some Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) experts. The research plan considered suggestions from those meetings and specialists to the extent possible. This paper reports the results of the 2017/18 krill and oceanographic survey conducted under the NEWREP-A.

RESEARCH METHODS

Research vessel

Two research vessels, *Yushin-Maru No.2* (*YS2*; 747 GT: Figure 1) owned by Kyodo Senpaku Co. Ltd., and the trawler type vessel *Kaiyo-Maru No.7* (*KY7*; 649 GT: Figure 2) owned by Kaiyo Engineering Co. Ltd., were used for the krill and oceanographic survey.

Research area and period

The research area was comprised between 165°E and 145°W, south of 60°S (eastern part of Area V and western part of Area VI). The area V-E was divided into northern and southern strata by a line 69°S. Balleny Islands and Scott Island exist in northern strata. The southern strata extends near the ice shelf and includes the area south of

69°S east of 170°W in the Ross Sea. Area VI-W was divided into northern and southern strata by a line 45 n.miles from the ice edge. The ice edge line was defined by observation of ice edge by the vessels as well satellite information base on National Snow and Ice Data Center (USA, Colorado).
The *YS2* surveyed the whole survey area for 73 days (from 10 December 2017 to 20 February 2018), *KY7* surveyed the northern part of V-E and VI-W for 44 days (from 10 December 2017 to 22 January 2018), excluding transit and logistical reasons respectively. Both vessels started the survey in VI-W westward from 145°W at 10 December. In early December, the ice edge existed approximately 65°S in VI-W and the polynya occurred between 170°E and 150°W, south of 75°S in the Ross Sea. The polynya widened to 70°S for an ice free region in early January, therefore *YS2* was able to enter the southern part of V-E in the Ross Sea on 12 January. Otherwise, *KY7* kept westward survey to the northern part of V-E.

Trackline design
The trackline was designed for the main purpose of this survey that is, the cetacean sighting survey for 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, Isoda *et al*., 2016, 2017; Figure 3). At area VI-W, the trackline consisted of a zigzag course changing direction at each 5°00' longitudinal degree intervals in the northern stratum and at 2°30' in the southern stratum. The trackline of the northern of stratum area VI-W also consisted of a zigzag course changing direction at each 5°00' longitudinal degree intervals. Otherwise, the trackline of the southern Area of V-W was set zigzag in north and south to westward or eastward in the Ross Sea. The zigzag course changed direction at 1°30' latitudinal degree intervals. A randomized start point was determined based on the IWC SC guidelines (IWC, 2012).

Echosounder
The *YS2* was equipped with a Quantitative Echosounder (EK80; Simrad, Norway). EK80 was operated with frequencies at 38 kHz, 120 kHz and 200 kHz. The transducers were hull-mounted at a depth of 4.3 m below the sea surface. Maximum data recording depth was set at 500 m. Acoustic data were recorded continuously while *YS2* steamed on the predetermined tracklines at a speed of 11.5 knots. Standard calibration of the EK80 was made using a standard methods (Demer *et al*., 2015) in the vicinity of Japan and also in the research area to determine the likely effective acoustic sampling range and a potential for detecting krill for multiple frequencies over the required survey depth. The *KY7* was equipped with a Quantitative Echosounder (EK60; Simrad, Norway). EK60 was operated with frequencies at 38 kHz, 120 kHz and 200 kHz. The transducers were hull-mounted at a depth of 4.7 m below the sea surface. Maximum data recording depth was set at 500 m. Acoustic data were recorded continuously while *KY7* steamed on the predetermined tracklines at a speed of 11.0 knots. Standard calibration (Demer *et al*., 2015) of the EK60 and the EK80 was conducted in the vicinity of Japan and also in the research area. Following recommendations from specialists, calibration between EK80 and EK60 echosounders was conducted when *YS2* and *KY7* passed nearby around the crossing tracklines of northern and southern strata. The results of calibration between EK80 and EK60 will be reported in related CCAMLR working group and/or the mid-term review of NEWREP-A.

Small ring net sampling
The *YS2* was equipped with a 1.5 mm mesh size small ring net designed by Nippon-Kaiyo Co., Ltd. Japan for vertical plankton hauls. The main purpose of this net sampling was not collecting quantitative information (*e.g*. number of individuals and length frequency distribution) but rather collecting qualitative information (*e.g*. species occurred in the echo signs) because the net is too small for collection representative sample of krill. The net had a 1.0 m mouth diameter and a 3.0 m length. During the sampling, the vessel stopped the engine so that the net could be hauled vertically. In principle net sampling conducted at the area, where is confirmed the echo sign.

The *KY7* was also equipped with the same small ring net as used in *YS2*. 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 a sufficient amount of samples to examine length frequency of krill and if the composition of plankton samples was similar to those collected by IKMT, the result of the small ring net sampling are somewhat useful. The small ring net hauls were carried out the same as in *YS2*, but were only conducted where IKMT collected swarms of krill.

Data Storage Tag Centi-ex (DST, Star Oddi CO., LTD, Iceland) were put on the mouth of the small ring net for recording temperature and depth at one second interval. The data of DST were moved to pc after salvaged and the data of PI (PI32; Simrad, Norway) sensor was read off the display directly. On *KY7*, a PI Sensor was put on the ring net in a similar and read off depth from display at one minute interval. The lighting system LED used for attracting krill in the 2015/16NEWREP-A was not used following recommendation by CCAMLR WG-SAM (Table 1: CCAMLR, 2016).

The target depth of net sampling was set based on depth of the echo sign but the maximum depth was around 200 m. The depth of the net mouth was checked by wire during hauling, then 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 a time. Hauling speed of the net was about 1.0 m/s that depended on sea state. All sampling was conducted during day time.

Issak-Kid Midwater Trawl (IKMT) sampling

The *KY7* was equipped with an IKMT designed by Nippon-Kaiyo Co., Ltd. Japan. The purpose of IKMT sampling was collecting quantitative information for krill (e.g. determination of the species occurring in echo signs and representative krill length frequencies). The IKMT was 3.66 m in mouth diameter and 18.43 m (ten feet) length. During the sampling, the *KY7* steamed about 2.0 knots. Similar to small ring net, DST or PI sensors were installed at the mouth of the IKMT to record actual depth of the net.

The target depth of IKMT 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 of the *KY7* by PI sensor. Towing speed of IKMT was 1.0 m/s. The 0.5 mm mesh size was used for both small ring net and IKMT for the comparison of the two types of nets. All sampling is conducted during day time.

Krill sample treatment

Simple krill length measurements (AT) were conducted on board of the research vessels. Measurement point of AT is from the front of the eye to the tip of the telson, the thin, tapered triangular plate at the end of the abdomen to the nearest 1 mm (CCAMLR, 2011). Plankton samples were kept in bottles with 10% formalin and/or frozen at -20°C for further analysis in the laboratory.

Oceanographic observation

Hydraulic pressure, temperature, salinity, chlorophyll-*a* and dissolved oxygen were recorded from sea surface to 500 m depth using Conductivity-Temperature-Depth profiler (CTD) SBE 19 plus V2 SeaCAT (Sea-Bird Electronics, USA) by *YS2*, SBE 19 plus SeaCAT (Sea-Bird Electronics, USA) by *KY7*. In principle, CTD casting was planned to be conducted at each latitude on tracklines with intervals of about 70 n.miles. When seawater sampling was carried out, targeting depth of CTD was set to 1,000 m depth. Seawater sampling was planned to be distributed evenly across survey area. The data of CTD was transferred to a pc at the laboratory.

Seawater sampling was carried out for the calibration of CTD sensors. Niskin water sampling bottle Model-1010 1.2L (General Oceanics, Inc., USA) by *YS2* and Model-1010 1.7L (General Oceanics, Inc., USA) by *KY7* were dropped to take seawater at depth from 0 m to 200 m every 20 m. Depth information of sampling bottle was based on the angle of the wire while operating, accurate depth of sampling bottle from DST or PI sensor were recorded at the laboratory. The water was kept in a 250 mL clarity seawater bottle (WOCE type 5419-C, Rigosha, Japan) for salinity calibration of CTD and was stored at about 4°C. For chlorophyll-a calibration of CTD, sampled water was also stored in 100 mL bottles after paper filtering (233303 GF/F 2.5cm, Whatman, UK). The filter papers were kept in 8 mL centrifugal tubes (60.452, Sarstedt, Germany) filled with dimethylformamide and were stored in a freezer at about -20°C (Saito, 2007).

Principle of priorities and time allocation for each survey components

The dedicated sighting survey was the highest priority component of this cruise for both vessels, however we tried to conduct krill and oceanographic surveys to the maximum extent. In principle, almost all time was allocated to the sighting survey to secure sufficient sighting survey effort in the survey area. About an hour per day was allocated for net sampling and CTD.

RESULTS AND DISCUSSION

Echosounder

Calibrations of echosounders were made on 8 November 2017 (*YS2*) and on 5 November 2017 (*KY7*) before departure for the Antarctic. During the calibrations, the vessel's engines were stopped. The depth of anchoring for calibration was 35 m (*YS2*) and 52 m (*KY7*) in the vicinity of Japan. Calibrations in the survey area were made on 8 December 2017 by *YS2* and on 9 December 2017 by *KY7*. In the Antarctic anchoring at that depth could not be achieved, the drifting speed was approximate 0.7 knots. During the calibrations, the vessel's engines were stopped. The comparison between *YS2* and *KY7* quantitative echosounders was carried out on 20 and 25 December 2017. We followed basic concept of the methodology by Simmonds *et al*., (2005). The echosounder data were recorded by *YS2* and *KY7* moving in formation with one in the lead and the other 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 2 hours. As a result, calibrations between EK60 and EK80 were conducted in last and this year were difficult. When beginning of the calibrations, there were some echo signs, however, these echo signs decreased gradually. Next year, the comparison should be done in in the shallow waters in vicinity of Japan. Table 2 shows a summary of the total effort spent on the quantitative echosounder. The quantitative echosounder survey was conducted for a total of 6,608 n.miles along the tracklines (3,581 n.miles in area V-E and 3,027 n.miles in area VI-W). Figure 3 shows the actual track of the echosounder survey where data were recorded continuously.

Net sampling

Number and horizontal location of net sampling stations
The small ring net sampling was conducted at a total of 47 stations by *YS2* and *KY7* (31 stations in area V-E and 16 stations in area VI-W, Table 3 and Figure 4). Because of weather, sea ice conditions or survey priority reasons, some net sampling stations were skipped.

IKMT sampling was conducted at a total of 11 stations by *KY7* (three stations in area V-E and eight stations in area VI-W, Table 3 and Figure 4). 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.

Sampling contents
A total of twelve prey species, including three euphausiids (Antarctic krill, ice krill and bigeye krill) and one fish (Antarctic silverfish: *Pleuragramma antarcticum*), were identified in the 58 net sampling contents. In addition, some *Copepoda*, *Hydrozoa*, *Ctenophora*, *Beroidae*, *Chaetognatha*, *Polychaeta*, *Pteropoda* and *Amphipoda* were confirmed.

Horizontal and vertical distribution of krill species
Tables 4 and 5 show the summary of frequencies of occurrence of krill species and *Copepoda* sampled at the small ring net sampling and IKMT sampling stations, and figures 5, 6 and 7 show the horizontal distribution by krill species. Antarctic krill was sampled at 31 stations in entire of survey area (Fig. 5). Distribution of surface water temperature was in the range of -1.7°C to 1.5°C. They were sampled at depths of 21 m to 203 m. The range of body length was from 10 mm to 51 mm. This was consistent with a previous study (Taki *et al*. 2008). Ice krill was sampled at five stations in the southern part of the Ross Sea (Fig. 6). Distribution of surface water temperature was in the range of -0.9°C to 1.2°C. They were sampled only on the continental shelf. The range of body length was from 16 mm to 41 mm. *Thysanoessa* spp. were sampled at 10 stations (Fig. 7). Distribution of surface water temperature was in the range of -1.7°C to 5.9°C. They were sampled at depths of 22 m to 273 m. The range of body length was from 7 mm to 21 mm.

Comparison of small ring net and IKMT sampling
The small ring net and IKMT sampling was conducted with careful confirmation of krill swarm location by the monitor of quantitative echosounder and pilot vessel sensitively. Simultaneous samplings with the small ring net and IKMT were conducted at four stations by *KY7*. At two cases, Antarctic krill was sampled by both small ring net and IKMT. However, for another two cases, the results from both nets were not consistent. In the 2016/17 NEWREP-A survey for three cases, the results from both nets were not consistent (Wada *et al.*, 2017). 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.

Oceanographic observation
The Oceanographic observation by CTD was conducted at 112 stations by *YS2* and *KY7* (60 stations in area V-E and 52 stations in area VI-W, Table 6 and Figure 8 and 9). Before the cruise departure the CTD had been calibrated by Sea-Bird Electronics in the USA. The stations were separated approximate 70 n.miles for covering each latitude on the trackline. During the previous JARPAII surveys the average distance between stations was about 60 n.miles (Watanabe *et al*., 2014). The seawater sampling was conducted at 16 stations at the same locality where CTD observations were taken. These station were distributed evenly across the survey area at a distance of approximately 120 n.miles in radius. Ten stations in area V-E and six stations in area VI-W by *YS2* and *KY7* were sampled (Table 6 and Figure 8). A total of 176 seawater samples were taken then kept in clear bottles for salinity calibration and filter paper filled with dimethyl formamide for chlorophyll-*a* calibration. Examination of seawater samples will allow identification of Upper Circumpolar Deep Water, Lower Circumpolar Deep Water, and Shelf Water based on correction of CTD data.

Response to recommendations of CCAMLR specialists and future works

Response to recommendations of CCAMLR specialists is summarised in Table 1. These issues included in Table 1 will be reported to the CCAMLR workshop and/or the mid-term review of NEWREP-A. The preliminary results of abundance estimation of krill using the data sets of NEWREP-A and based on the standard abundance estimation method established by CCAMLR will be reported in the related working group of CCAMLR in the future. This method will be discussed in SG-ASAM this year.

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Table 1. Response to some recommendations of 2016 CCAMLR WG-SAM (CCAMLR, 2016)

Item	Paragraph	Note	Current state
Note for the survey	2.8	The sampling for krill was not likely to be adequate for validating the composition of acoustic marks obtained by the echosounders.	The primary objective is not abundance estimate of krill but whales. We tried to increase the numbers of net sampling. At 2017/18, net sampling was carried out at 58 stations.
	2.8	The size of the net is likely to be too small and is not being used to target the acoustic marks, but to identify species existing at the stations.	IKMT was introduced by *KY7* since 2016/17 NEWREP-A. The IKMT has 3.66 m mouth and 18.43 m lengths. It is one of standard nets for CCAMLR survey.
	2.8	The use of a light on the net may lead to biased estimation of what organisms are being detected by the acoustics.	LED light system had stopped since 2016/17 NEWREP-A.
	2.8	Insufficient krill are being obtained to estimate the length frequency of krill detected by the acoustics.	At 2016/17NEWREP-A, IKMT was introduced by *KY7* since 2016/17 NEWREP-A.
	2.9	No clear description of the questions being addressed. (The sampling is insufficient to determine the relationship of whales to the densities of krill or physical ocean habitat.)	The primary objective is abundance estimate of whales. We tried to increase the numbers of net sampling. At 2017/18, net sampling was carried out at 58 stations.
	2.9	Need random sampling across the area to better estimate and increase in the number of sampling locations.	At 2017/18NEWREP-A, net sampling were conducted for confirming echo sign.
	2.9	Power analyses is important to determine an appropriate number of stations.	The primary objective is not abundance estimate of krill but whales. We tried to increase the numbers of net sampling.

Table 2. Summary of quantitative echosounder survey in 2017/18 NEWREP-A.

Area	*YS2*		*KY7*		Total
	days	n.miles	days	n.miles	n.miles
V-NE	12	808	14	1,076	1,884
V-SE	24	1,697	-	-	1,697
VI-NW	19	693	16	808	1,501
VI-SW	16	629	16	576	1,205
VI-SW(Below69°S)	4	321	-	-	321
Total	73*	4,148	44*	2,460	6,608

(*The survey was conducted some area in same day)

Table 3. Number of net sampling stations in 2017/18 NEWREP-A.

Area	Small ring net			*IKMT*
	YS2	*KY7*	Total	*KY7*
V-NE	6	2	8	3
V-SE	23	-	23	-
VI-NW	3	1	4	3
VI-SW	6	2	8	5
VI-SW(Below69°S)	4	-	4	-
Total	42	5	47	11

Table 4. Summary of small ring net sampling in 2017/18 NEWREP-A.

Area	*Euphausia superba*		*Euphausia crystallorophias*		*Thysanoessa spp.*		*Euphausiids*		*Copepoda*		Other Zooplankton	
V-NE	3	38%	0	0%	5	63%	2	25%	5	63%	7	88%
V-SE	9	39%	4	17%	0	0%	4	17%	14	61%	13	57%
VI-NW	2	50%	0	0%	2	50%	0	0%	2	50%	3	75%
VI-SW	7	88%	0	0%	2	25%	0	0%	3	38%	2	25%
VI-SW(Below69°S)	1	25%	1	25%	1	25%	3	75%	4	100%	4	100%
Total	22	47%	5	11%	10	21%	9	19%	28	60%	29	62%

Table 5. Summary of IKMT in 2017/18 NEWREP-A. (The IKMT was not conducted in area V-SE.)

Area	*Euphausia superba*		*Euphausia crystallorophias*		*Thysanoessa spp.*		*Euphausiids*		*Copepoda*		Other Zooplankton	
V-NE	2	67%	0	0%	0	0%	0	0%	1	33%	3	100%
VI-NW	2	67%	0	0%	0	0%	0	0%	1	33%	3	100%
VI-SW	5	100%	0	0%	0	0%	0	0%	0	0%	2	40%
Total	9	82%	0	0%	0	0%	0	0%	2	18%	8	73%

Table 6. Number of oceanographic stations in 2017/18 NEWREP-A.

Area	CTD			Seawater Sampling			DST		
	YS2	*KY7*	Total	*YS2*	*KY7*	Total	*YS2*	*KY7*	Total
V-NE	12	16	28	2	3	5	6	0	6
V-SE	32	0	32	5	0	5	23	-	23
VI-NW	11	13	24	1	2	3	3	2	5
VI-SW	10	12	22	1	1	2	6	0	6
VI-SW(Below69°S)	6	0	6	1	0	1	4	-	4
Total	71	41	112	10	6	16	42	2	44

Figure 1. Research vessel *Yushin-maru No.2* (*YS2*).

Figure 2. Research vessel *Kaiyo-maru No.7* (*KY7*).

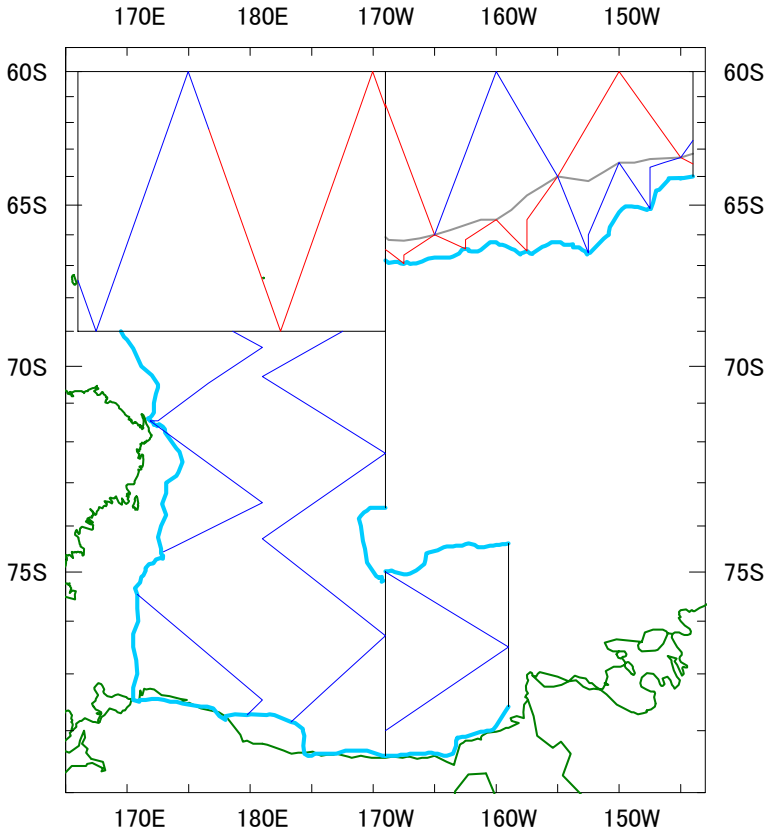

Figure 3. The track lines made by two research vessel in 2017/18 NEWREP-A.
(Blue line: surveyed track lines of *YS2*, Red line: surveyed track lines of *KY7*, Turquoise line: ice edge, Gray line: boundary of VI-NW and VI-SW, Green line: Antarctic continent)

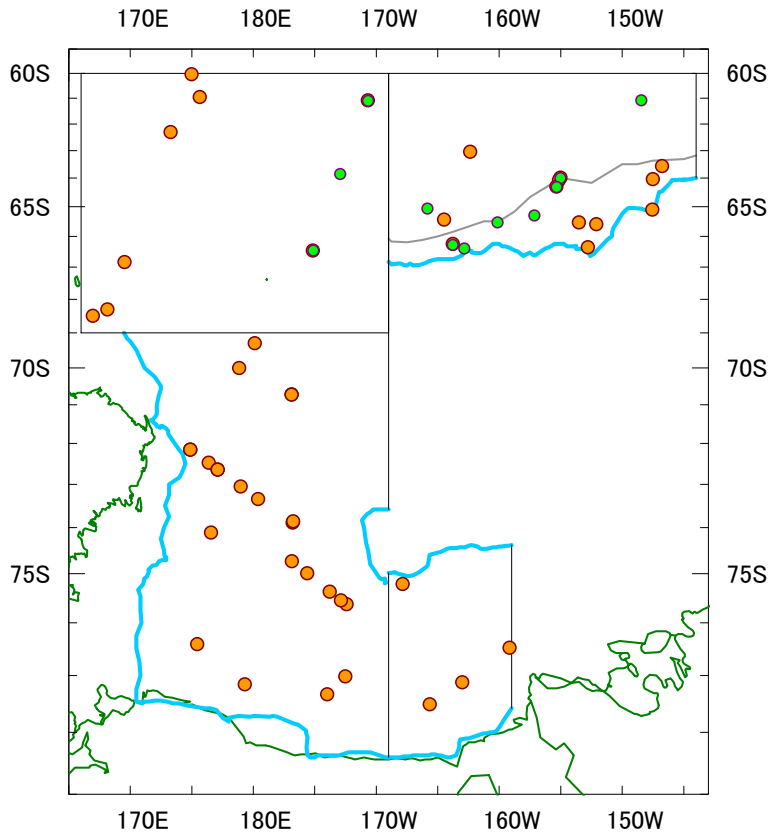

Figure 4. Sampling stations of small ring net and IKMT in 2017/18 NEWREP-A.
(Orange circle: small ring net, Green circle: IKMT)

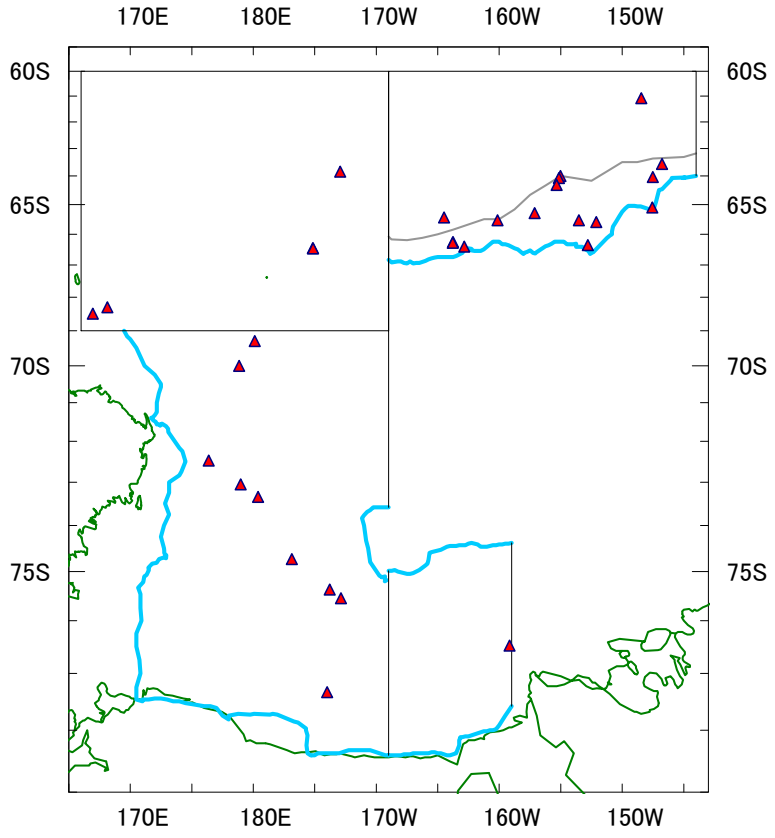

Figure 5. Sampling positions of Antarctic krill in 2017/18 NEWREP-A.

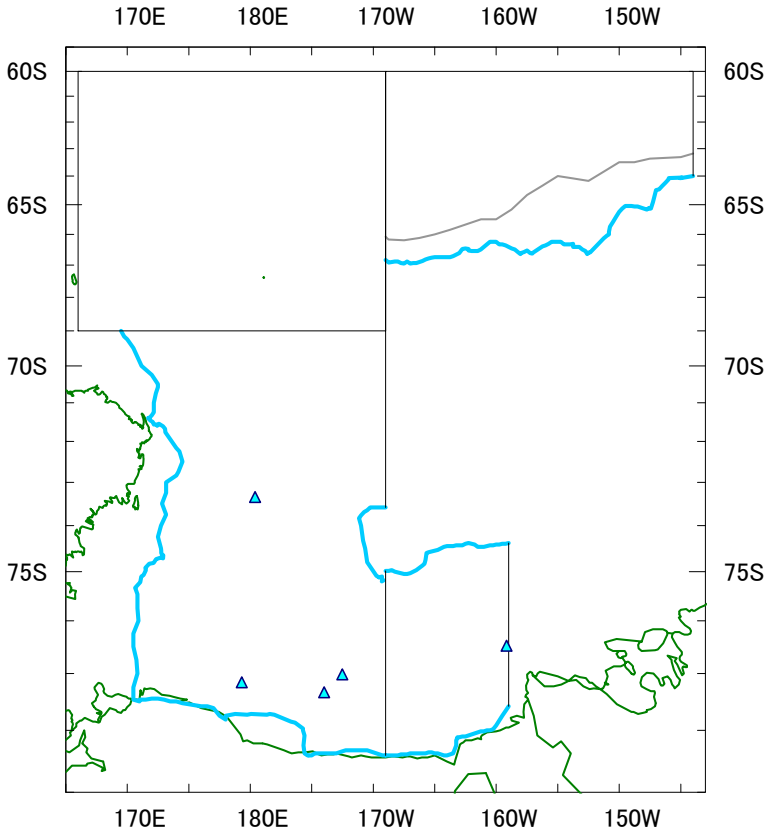

Figure 6. Sampling positions of ice krill in 2017/18 NEWREP-A.

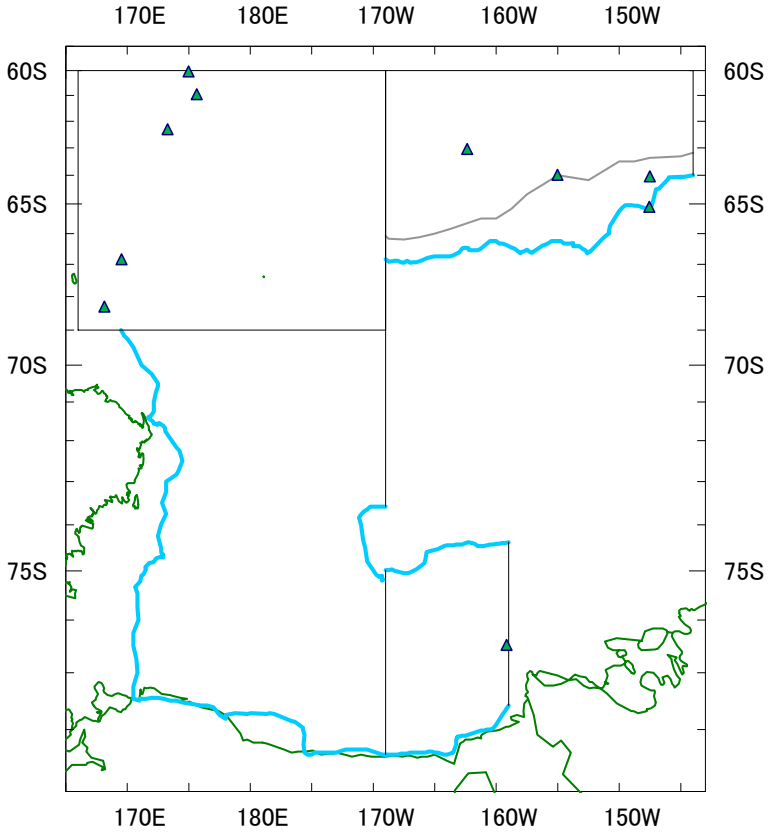

Figure 7. Sampling positions of *Thysanoessa spp.* in 2017/18 NEWREP-A.

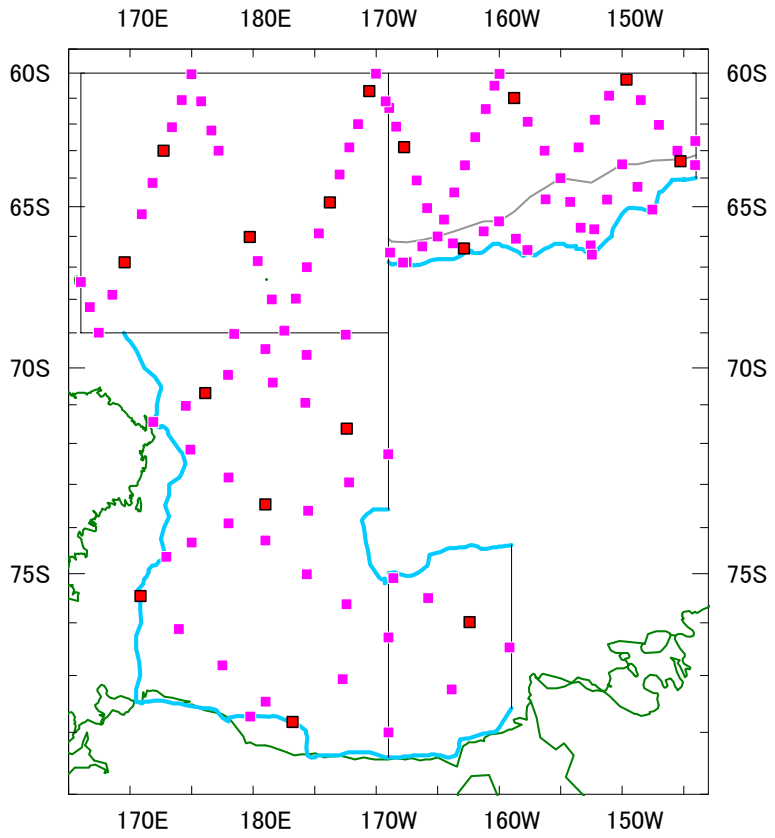

Figure 8. The stations of CTD and seawater sampling in 2017/18 NEWREP-A.
(Pink square: CTD, Red square: seawater sampling)

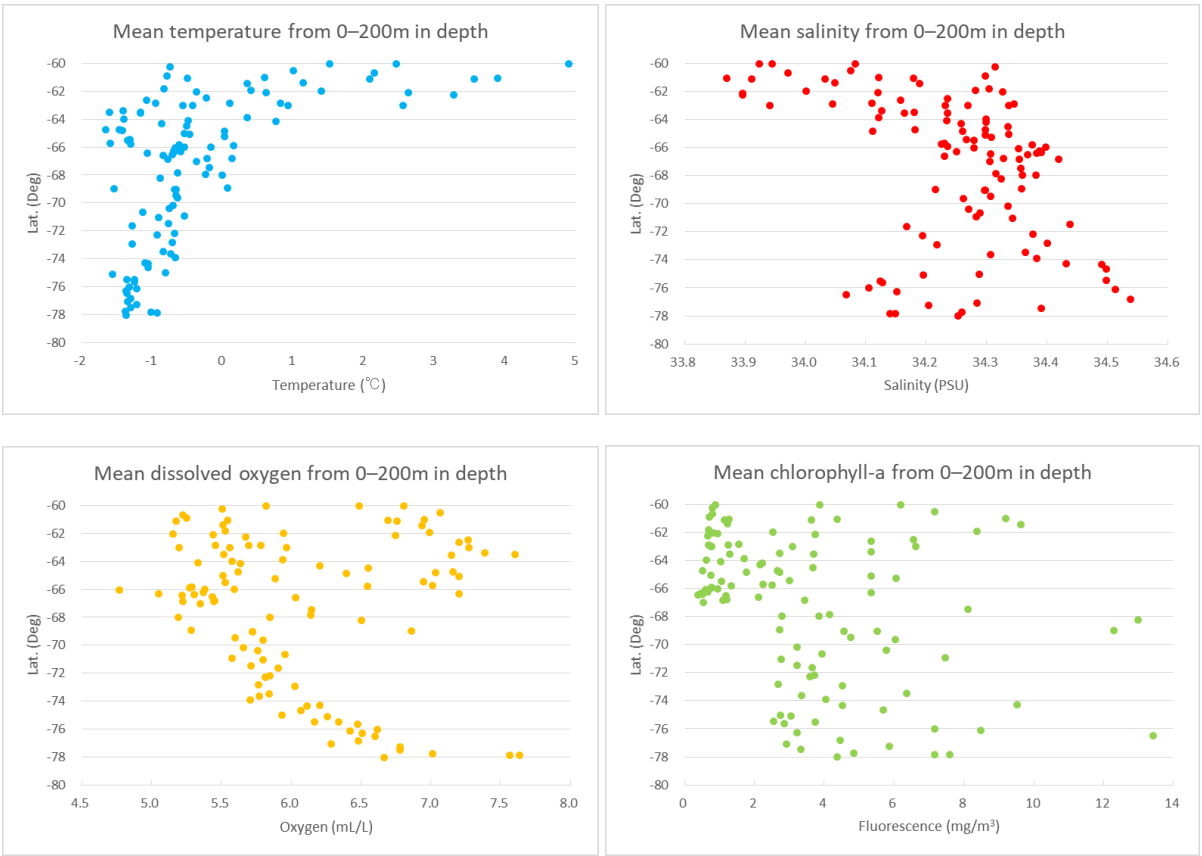

Figure 9. The Plot of average from 0 to 200m CTD data. (above left: Temperature, above right: salinity, below left: dissolved oxygen, below right: chlorophyll-*a*)