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ABSTRACT

The first dedicated sighting survey vessel-based krill survey was conducted in the Antarctic Area IV-E during the 2015/16 austral summer season as part of the ecological rsearch of NEWREP-A, associated with main objective II. The krill survey was conducted along the tracklines designed for a sighting survey. Acoustic data were recorded continuously for 31 days using a quantitative echosounder (EK80). Net samplings using a small ring net (1m in diameter) equipped with LED were carried out to identify species and size compositions of echo signs at 29 stations. Oceanographic observation was also conducted at 29 stations using a CTD. Krill and oceanographic data are being currently examined, and the results will be considered for the planning of the second survey in the 2016/17 season.

KEYWORDS: KRILL; ACOUSTICS; NET SAMPLING; SCIENTIFIC PERMITS; OCEANOGRAPHY; ANTARCTIC;

INTRODUCTION

As described in Appendix 8 of the Research Plan for the New Scientific Whale Research Program in the Antarctic Ocean (NEWREP-A) (Government of Japan, 2015a), two kinds of krill surveys were proposed: (i) annual krill surveys along a dedicated whale sighting survey, aimed to obtain a relative index of abundance (sighting survey vessel-based krill survey), and (ii) a dedicated krill survey that follows Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) standard methodology, aimed to obtain an absolute index of abundance (CCAMLR-type dedicated krill survey). In order to facilitate the international participation and collaboration, the latter will be conducted outside of, but coordinated with, NEWREP-A. The latter surveys will be conducted at least two times in the 12-year NEWREP-A period. Oceanographic surveys were also planned by NEWREP-A, to be conducted during the krill surveys.

Data on krill and its environment in the Antarctic is relevant for the main objective II of the NEWREP-A, which is 'Investigation of the structure and dynamics of the Antarctic marine ecosystem through building ecosystem models'. Specifically krill biomass estimates will be used as input data for the development of ecosystem models.

The plan for the 2015/16 austral summer season of the sighting survey vessel-based krill survey was presented and discussed at the 2015 International Whaling Commission Scientific Committee (IWC SC) (Government of Japan 2015b).

This paper presents the results of the field work of the first sighting survey vessel-based krill survey in 2015/16, as a part of ecological research of NEWREP-A.

RESEARCH METHODS

Research area

The research area was comprised between 115°E and 130°E, south of 60°S (eastern part of Area IV).

Research vessel

The research vessel *Yushin-Maru No.3* (*YS3*; 742 GT) owned by Kyodo Senpaku Co. LTD., was used for the survey.

Trackline design and timing

Tracklines were designed for the whale sighting surveys under the DISTANCE sampling (Buckland *et al*. 2015) to estimate abundance of large whales (Figure 1). Trackline design was the same as that in the IDCR/SOWER surveys, and followed IWC SC guidelines (Isoda, 2016). The survey was planned for the daytime from one hour after sunrise to one hour before sunset with maximum of 12 hours.

Echosounder survey
The *YS3* was equipped with a Quantitative Echosounder (EK80; Simrad, Norway). EK80 operates with frequencies at 38kHz, 120kHz and 200kHz. 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 would be recorded continuously while *YS3* steamed on the predetermined tracklines at a speed of 11.5 knots. Calibration of the EK80 was made in Japan and in the research area to determine the likely effective acoustic sampling range and potential for detecting krill for multiple frequencies over the required survey depth.

Net sampling survey
The *YS3* was also equipped with a small ring net designed by Nippon-Kaiyo Co., Ltd. Japan. The net was 1m in mouth diameter and 3m length. To investigate the efficiency of sampling, two mesh sizes were used 1.5mm or 4.5mm. During the sampling, the vessel stopped the engine so that the net could be towed vertically. In principle net sampling was planned to be conducted once a day. It took approximately average 6 minutes per haul without time for set up. The main purpose of the net sampling was not collecting quantitative information (e.g. number of individuals and length frequency distribution) but collecting qualitative information (e.g. species occurred in echo signs) because the net used in this survey was not suitable for collection representative sample of krill. Such sampling will be carried out by dedicated krill survey.

Temperature Depth Recorder (TDR) (AL1, Ishida Engineering, Japan) was put in the mouth of the net for recording temperature and hydraulic pressure. Net sampling was conducted with Light Emitting Diode (LED) with an expectation of attracting krill so that number of sampled individuals would increase as demonstrated by previous study (Wiebe *et al*., 2004). 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) were mounted in the mouth of the net. In this study, no specific experiment was conducted to test effect of light on sampling as the main aim was to test whether krill could be sampled by using the small ring net.

The target depth of net sampling was set based on depth of echo sign but maximum depth was 200m. If the net was attached with LED and digital compact camera, the maximum depth was switched to 100m (considering pressure capacity). The depth of the mouth was estimated from angle of wire by visual with protractor. Towing speed of the net was 1.0 m/s.

Preliminary standard measurements (AT) of krill sampled were carried out on board the *YS3*. 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 (CCAMLR, 2011). Samples were kept in 100mL or 500 mL bottle with 10 percent formalin for further analysis in the laboratory.

Oceanographic observation
Hydraulic pressure, temperature, salinity, chlorophyll and oxygen concentrations were recorded from sea surface to 500 m water depth using a CTD (SBE 19 plus V2 SeaCAT, Sea-Bird Electronics, USA). In principle, CTD casting was planned to be conducted once a day. It took in average 27 minutes per cast without time for set up. The data of CTD was uploaded to conversion by a manual (Sea-Bird Electronics, Inc., 2013).

Seawater sampling was carried out for calibration of sensors. Niskin water sampling bottle (Model-1010 1.2L, General Oceanics, Inc., USA) was dropped to take seawater depth from 0 to 200m by every 20m. The water was kept in 2 bottles. A 250mL clarity seawater bottle (WOCE type 5419-C, Rigosha, Japan) for salinity calibration of CTD, which was stored at about 4°C. The second was a 100mL bottle for chlorophyll calibration of CTD. Water in this bottle was filtrated using paper filter 233303 GF/F 2.5cm, Whatman, UK. The filter paper was kept in 8mL centrifugal tubes (60.452, Sarstedt, Germany) filled with dimethylformamide. The tubes were stored in freezer about -20°C (Saito, 2007). The calibration will be carried out in the laboratory.

Principle of priorities and time allocation for each components
Priorities of survey components are as follows (from high to low): sighting, photo-identification, biopsy sampling, satellite tracking, echosounder, net sampling and CTD. In principle, almost all time was allocated to sighting survey to secure sufficient sighting survey effort in the survey area. Less than an hour per day at once was allocated for net sampling and CTD.

RESULTS OF THE FIELD WORK

The *YS3* was stayed in the research area for 50 days, from 27 Decmber2015 to 14 February 2016. The multidiscipline survey in the research area was conducted for 37 days from 5 January to 10 February 2016. Trials

of the equipment (e.g. calibration of echosounder, test of winch) were held for 9 days from 27 December 2015 to 4 January 2016. Table 1 shows a summary of the effort spent for the quantitative echosounder, and the number of stations for net sampling and CTD casting.

Echosounder survey

Calibration of the EK80 in Japan was made on 14 October and 11 November 2015. In the research area calibration was made on 27 and 31 December 2015. During the calibration in Japan the engine was stopped and the vessel was anchored at a depth of 32m. However, in the research area, the engine was stopped but the vessel was not anchored, and drifted at a speed of 0.5knots.

Figure 2 shows the actual tracklines for the echosounder survey, where data were recorded continuously. The echosounder survey was conducted for 31 days, and obtained data for 1,571.1n.miles along the tracklines. The parts off effort in Figure 2 were due to time spent by *YS3* confirming whale species outside of the tracklines. The data from the EK80 were recorded using a hard disk.

Net sampling survey

Number and geographical distribution of net stations

Net sampling was conducted at 29 stations, and Figure 3 shows the 29 stations on the survey tracklines. Other logistical considerations were also taken into account to decide whether to proceed with net sampling such as sea state, sea ice for safety reasons, and other research activities by the *YS3*.

Distribution of krill species

Table 2 shows the frequencies of occurrence of krill by the net sampling stations, and Figure 4 shows the geographical distribution by species. Antarctic krill (*Euphausia superba*) was sampled at 17 stations, 5 in the strata IV-NE and 12 in the strata IV-SE. Surface temperature in the stations where Antarctic krill was found ranged from -1.5 to 0.6°C, and the depth ranged from 30 to 100m. On board the vessel the AT measures were obtained. They ranged between 19 and 55mm. Ice krill (*Euphausia crystallorophias*) was sampled at 2 stations only in the strata IV-SE. Surface temperature in the stations where ice krill was found ranged from -1.0 to -0.6°C, and the depth ranged from 90 to 110m. On board the vessel the AT measures were obtained. They ranged between 21 to 31mm. Bigeye krill (*Thysanoessa macrura*) was sampled at 8 stations, 6 in the strata IV-NE and 2 in the strata IV-SE. Surface temperature in the stations where bigeye krill was found ranged from -0.5 to 0.7°C, and the depth ranged from 30 to 60m. On board the vessel the AT measures were obtained. They ranged between 9 to 23mm. Figure 4 also shows those stations where more than one species was sampled.

Evaluation of sampling net

During this survey net sampling was carried out with different mesh sizes and also with different types of LED (see summary of data collected in Table 3). The choice of no light, continuous light and strobe was arbitrary for this survey as the primary objective of the net tows was not testing effect of the choices on sampling efficiency but sampling of krill. Such a test would be difficult from the sighting survey vessel because of limitation of available equipment and number of hauls from the vessel. Further consideration of how to conduct such a test will be required if necessary. A total of 18 videos were taken by a digital compact camera that was mounted on the ring of the net. TDR casting was conducted at 28 stations at the same place as the net sampling.

Oceanographic observation

Figure 3 shows 29 stations where oceanographic survey was carried out by CTD. These stations were separated between 40 and 80n.miles. During the previous JARPAII surveys the average distance among stations was about 60n.miles. In five cases oceanographic surveys were conducted at the same locality of the net sampling. Data are being analyzed.

Figure 3 also shows the four stations where seawater sampling occurred. Depth information for sampling was based on the information from the EK80. Temperature information for sampling was based on the information from the CTD. Samples are being examined.

CONCLUDING REMARK

This document reported the field work and data obtained during the first dedicated sighting vessel-based krill survey under the NEWREP-A. The survey was conducted as originally planned. However the performance of this kind of survey will be evaluated once the ongoing analyses are completed.

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Table 1. Summary of sighting survey vessel-based krill survey in the 2015/16 NEWREP-A.

Stratum	Quantitive Echosounder		Net Sampling (Stations)	CTD Casting (Stations)	Seawater Sampling (Stations)
	(days)	(n.miles)			
IV-NE	15	935.7	12	15	2
IV-SE	16	635.5	17	14	2
Total	31	1,571.1	29*	29**	4

* Excluding trials of the equipment and empty haul. ** Excluding trials of the equipment.

Table 2. Number of net stations by sampled species in the 2015/16 NEWREP-A.

Stratum	Number of stations	*Euphausia superba*		*Euphausia crystallorophias*		*Thysanoessa macrura*		Copepod		Other	
IV-NE	12	5	42%	0	0%	6	50%	7	58%	12	100%
IV-SE	17	12	71%	2	12%	2	12%	4	24%	7	41%
Total	29	17	59%	2	7%	8	28%	11	38%	19	66%

Table 3. Number of net sampling stations by mesh size and LED mode in the 2015/16 NEWREP-A.

Stratum	*1.5mm mesh*			*4.5mm mesh*		
	Lighting	*Strobe*	*None*	*Lighting*	*Strobe*	*None*
IV-NE	3	2	2	2	1	2
IV-SE	2	3	3	3	3	3
Total	5	5	5	5	4	5

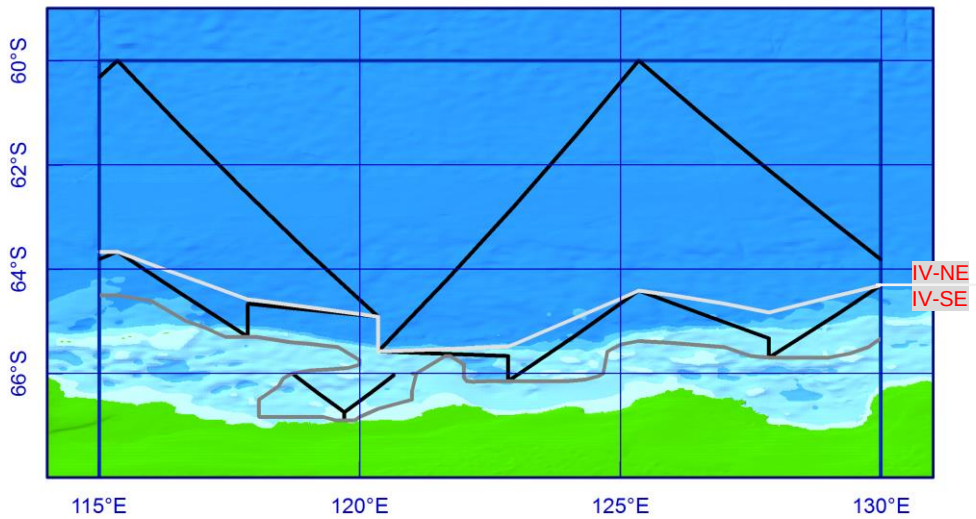

Figure 1. Research area and planned tracklines of the sighting survey vessel-based krill survey in the 2015/16 NEWREP-A. (Mazarin line: Research area, Dark gray line: Ice edge, Light gray line: Boundary line between IV-NE and IV-SE, Black line: Trackline, Aqua: Antarctic shelf, Green: Antarctic continent)

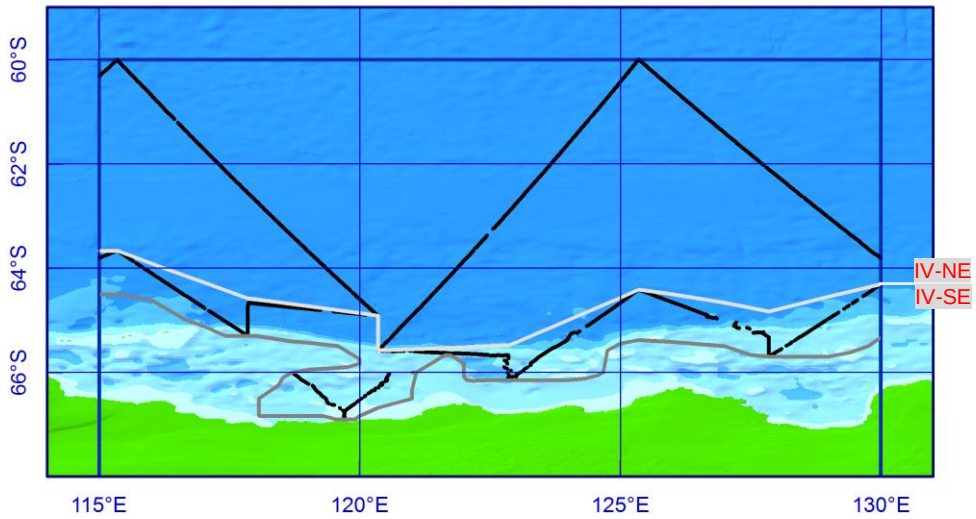

Figure 2. Echosounder survey in the 2015/16 NEWREP-A.

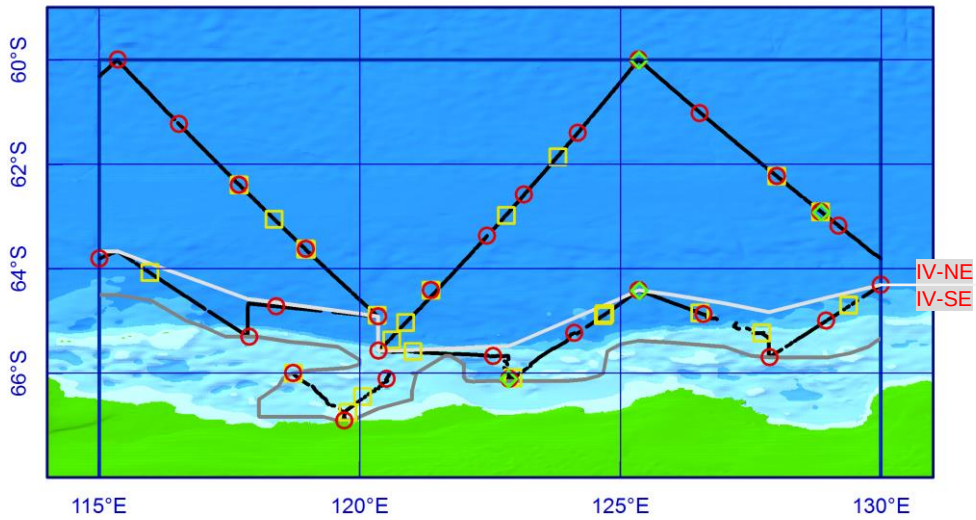

Figure 3. CTD, net sampling and seawater sampling station in the 2015/16 NEWREP-A.
(Red circle: CTD, Yellow square: Net sampling, Green diamond: Seawater sampling)

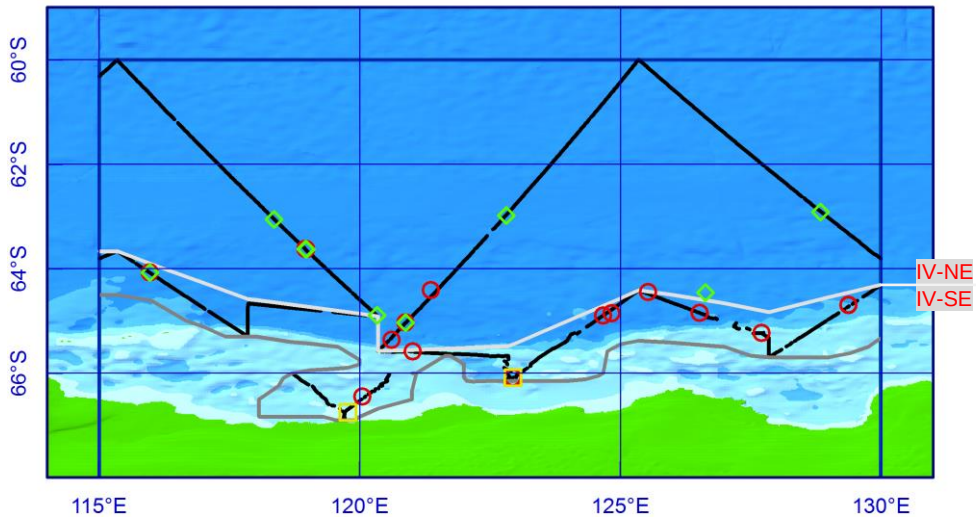

Figure 4. Sampled each krill by net sampling in the 2015/16 NEWREP-A.
(Red circle: Antarctic krill, Yellow square: Ice krill, Green diamond: Bigeye krill)