Cruise Report of the Second Phase of the Japanese Whale Research Program under Special Permit in the Western North Pacific (JARPN II) in 2010 (part I) - Offshore component –

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ABSTRACT

The ninth cruise of the full-scale Second Phase of the Japanese Whale Research Program under Special Permit in the Western North Pacific (JARPN II) -offshore component- was conducted from 9 June to 22 August 2010 in sub-areas 7, 8 and 9 of the western North Pacific. The objectives of the JARPN II are (a) feeding ecology and ecosystem studies, (b) monitoring environmental pollutants in cetaceans and the marine ecosystem and (c) elucidation of stock structure. Target species in the whale component of JARPN II are the common minke whale *Balaenoptera acutorostrata*, sei whale *B. borealis*, Bryde's whale *B. edeni* and sperm whale *Physeter macrocephalus*. A total of five research vessels was used: one trawl survey vessel equipped with scientific echo sounder (TSV), one dedicated sighting vessel (SV), two sighting/sampling vessels (SSVs) and one research base vessel. A total of 3,749 n.miles was surveyed in a period of 75 days by the SSVs. A total of 15 common minke, 333 sei, 136 Bryde's, 193 sperm, 36 fin and 10 blue whales were sighted by the SSVs and NM. A total of 14 common minke, 100 sei, 50 Bryde's and three sperm whales was sampled by the SSVs. All whales sampled were examined on board the research base vessel. Common minke whales fed mainly on Pacific saury (*Cololabis saira*). Bryde's whales fed mainly on Japanese anchovy (*Engraulis japonicus*) and sei whales fed mainly on copepods and Japanese anchovy. Dominant preys in the stomach of three sperm whales were various kinds of squids, which inhabit the mid- and deep-waters. These data will be used in the development of ecosystem modelling.

KEYWORDS: PACIFIC OCEAN; COMMON MINKE WHALE; BRYDE'S WHALE; SEI WHALE; SPERM WHALE; MONITORING; FOOD/PREY; ECOSYSTEM; SCIENTIFIC PERMITS

INTRODUCTION

The JARPN II started as a full-scale research program in 2002. It has the following research objectives: i) feeding ecology and ecosystem studies, ii) monitoring environmental pollutants in cetaceans and the marine ecosystem and iii) elucidation of the stock structure (Government of Japan, 2002).

The full-scale JARPN II plan involves two survey components: the 'offshore' survey was covered by the *Nisshin Maru* research unit and two 'coastal' surveys (Sanriku and Kushiro) covered by small type catcher boats. The coastal component was necessary to cover the temporal and spatial gaps, which could not be covered by the *Nisshin Maru* unit (Government of Japan, 2002).

The research area of offshore component was set in sub-areas 7, 8 and 9, and the target species and sample sizes were set as follows: 100 common minke whales; 100 sei whales, 50 Bryde's whales and 10 sperm whales.

In this paper, we present an outline of the ninth full-scale survey of the JARPN II -offshore component-, which was conducted from 9 Jun to 22 August 2010.

MATERIALS AND METHODS

Research area

Sub-areas 7, 8 and 9, excluding the EEZ zones of foreign countries, comprised the research area of the SSV vessels. Sub-areas 9 and 13, excluding the EEZ zones of foreign countries, comprised the research area of the SV vessels (Figure 1). These sub-areas were further divided as follows:

Sub-area 7: Five small blocks (7N, 7MI, 7MO, 7SI and 7SO) stratified by taking into account satellite information on water temperature.

Sub-areas 8 and 9: Four small blocks were divided at 40ºN in each sub area (8N and 8S, 9N and 9S).

Research vessels

Five research vessels were used. The research base vessel *Nisshin Maru* (NM: 8,044GT) commanded the research and was the platform for biological examination of whale samples and processing of by-products. The *Yushin Maru* (YS1: 720GT) and *Yushin Maru* No.2 (YS2: 747GT) were used as the sighting/sampling vessels (SSVs), which conducted sighting activities, sampling of targeted whale species and various experiments and observations. The *Yushin Maru* No.3 (YS3: 742GT), was used as dedicated sighting vessel (SV). The Hokko maru (HK: 1246GT) was used for the investigation of the distribution and abundance of whale prey species with midwater trawl, MOHT, VMPS, twin NORPAC nets, and quantitative echosounder, and also to examine distribution of each whale species in relation to oceanographic and prey environments to estimate habitat and prey preference of each whale.

Survey components

The survey was composed of three main components: whale survey, sighting survey and prey species survey.

Whale survey
Vessels: Three research vessels (NM, YS1 and YS2)

Research area: Sub-areas 7, 8 and 9. In addition, a 'special monitoring survey' (SMS) was undertaken in some areas where the number of common minke, Bryde's and sei whales was expected to be abundant.

Research period Between 9 June and 22 August

Dedicated Sighting survey
Vessels: One research vessel (YS3)

Research area: Sub-areas 9 and 13

Research period: Between 9 June and 18 July

* A report of this sighting survey was presented in document SC/63/O6.

Cooperative survey on the prey species and whale sampling
Vessels: Four research vessels (NM, YS1, YS2 and HK)

Research area:

First period (Western block) : A part of sub areas 8 and 9 (NM, YS1, YS2 and HK)

Second period (Eastern block) : A part of sub area 9 (NM, YS1, YS2 and HK)

Research period:

First period (Western block) : Between 24 July and 29 July (NM, YS1, YS2 and HK)

Second period (Eastern block) : Between 30 July and 4 August (NM, YS1, YS2 and HK)

Methods for setting cruise track line

Whale survey
Track lines and allocation of vessels were made as in previous JARPN and JARPN II surveys (Fujise *et al.*, 1995, 1996, 1997, 2000, 2001, 2002, 2003; Ishikawa *et al.*, 1997; Zenitani *et al.*, 1999; Tamura *et al.*, 2004, 2005, 2006, 2009a, 2009b; Bando *et al.,* 2010; Matuoka *et al.*, 2008). The zigzag-shaped track line was established on an arbitrary basis in each sub-area. Furthermore, some 'special monitoring surveys' (SMS) were conducted in areas where the abundance of common minke whales, Bryde's and sei whales was expected to be high. Track

line in the SMS was designed separately from the original track line. Two SSVs were allocated to these tracks with the allocation being changed every day. The research course for the SSVs consisted of one main track and one parallel track established 7n.miles apart from the main course.

Dedicated Sighting survey
Apart from the sampling activities, an independent track line for dedicated sighting survey was designed in the research area. See details in SC63/O6.

Sighting surveys
Sighting procedure both for the whale survey and dedicated sighting survey was similar to the previous surveys of JARPN and JARPN II (Fujise *et al.*, 1995, 1996, 1997, 2000, 2001, 2002, 2003; Ishikawa *et al.*, 1997; Zenitani *et al.*, 1999; Tamura *et al.*, 2004, 2005, 2006, 2007, 2009a, 2009b; Bando *et al.*, 2010; Matsuoka *et al.*, 2008). In the research area sighting was conducted mainly under closing mode. Furthermore two modalities of sighting in closing mode were adopted, *NSC* and *NSS modes*, by taking into consideration weather and sea conditions. The *NSC* and *NSS modes* were the same as *BC* and *BS modes* in the previous JARPN surveys, respectively. The conditions to conduct surveys under *NSC mode* were similar to those established in Japanese sighting surveys conducted by the National Research Institute of Far Seas Fisheries (*i.e.* visibility of 2n.miles or more and wind force of 4 or below). The *NSS mode* was used under bad weather conditions such as heavy rain and fog when the collection of whale samples was still possible. This *NSS mode* was used only by SSV vessels. These two mode surveys were recorded separately for future analysis. Also an *ASP mode* was used (closing mode survey without sampling activities under normal sighting conditions).

Closing was performed mainly on sightings of common minke, Bryde's, sei and sperm whales. Furthermore closing was made on sightings of large whales, such as blue, humpback, right and fin whales. In these cases, closing was done in order to confirm species and school size and in order to conduct some experiments.

Sampling of common minke, Bryde's, Sei and sperm whales
The target species and sample sizes in the 2010 JARPN II offshore component were set as follows: 100 common minke whales; 100 sei whales, 50 Bryde's whales and 10 sperm whales.

Most of the whales sighted on the track line were approached for sampling. Furthermore sampling effort was applied outside the established research hours (Main time: 07:00-19:00 (12 hrs)), if collection of whale samples was considered possible.

For schools consisting of two or more animals, numbering was made for all the whales in the school; to set sampling order randomly in accordance with the table of random numbers (Kato *et al.*, 1989). Cow and calf pairs were not targeted for sampling.

Sampled whales were immediately transported to a research base vessel, where biological measurements and sampling were carried out.

Experiments
The following experiments and observations were conducted by the sighting/sampling vessels (*YS1* and *YS2*):

1. Sighting distance and angle experiments to examine the precision of sighting data.
2. Biopsy sampling on gray, blue, fin, humpback and right whales.
3. Photographic records of natural marks on blue, humpback and right whales.
4. Feeding behaviour patterns of large whale species (blue, fin, sei, Bryde's, common minke, humpback, right and sperm whales).

The following experiments and observations were conducted on board the research base vessel (*NM*):

1. Observations of marine debris in the sea were conducted from the wheelhouse (during transit cruises)

The following experiments were conducted on board the prey survey vessel (*HK*):

1. Estimate abundance of prey species of sei and other large whale species (see details in Appendix 1).
2. Observation of whale distribution (see details in Appendix 1).
3. Oceanographic observations using CTD and OPCS (see details in Appendix 2).

RESULTS AND DISCUSSIONS

Searching distance

Track line set by the two sighting/sampling vessels (SSVs) is shown in Figure 2. The total searching distance for SSVs was 3,749n.miles.

Sightings of common minke, Bryde's, sei and sperm whales

Sighting and sampling vessels (SSVs) and NM

A total of 15 schools (15 individuals) of common minke whales was sighted, consisting of 6 schools (6 individuals) of primary and 9 schools (9 individuals) of secondary sightings. For sei whale, 188 schools (333 individuals) were sighted, consisting of 89 schools (148 individuals) of primary sightings and 99 schools (185 individuals) of secondary sightings. For Bryde's whale, 104 schools (136 individuals) were sighted, consisting of 83 schools (110 individuals) of primary sightings and 21 schools (26 individuals) of secondary sightings. For sperm whale, 94 schools (193 individuals) were observed, consisting of 56 schools (108 individuals) of primary sightings and 38 schools (85 individuals) of secondary sightings (Table 1).

Figure 3 shows the distribution of common minke, sei, Bryde's and sperm whales sighted by the SSVs in the sub-areas 7, 8 and 9. Sei whales and Bryde's whales were sighted mainly in offshore sub-areas 8 and 9. On the other hand, common minke whales were sighted in sub-area 9 only. Sperm whales were widely distributed in the research area.

Sightings of other large cetacean species

Sighting and sampling vessels (SSVs) and NM

Table 1 also shows the number of sightings for other large whale species made by the SSVs, including large baleen whales such as blue (10 schs./10 inds.), fin (30 schs./36 inds.), and humpback whales (5 schs./6 inds.).

Sampling numbers and biological research for common minke, Bryde's, sei and sperm whales

A total of 14 common minke whales (Male: 12 individuals, Female: 2 individuals), 100 sei whales (Male: 43 individuals, Female: 57 individuals), 50 Bryde's whales (Male: 25 individuals, Female: 25 individuals) and three female sperm whales were sampled. Struck and lost did not occurr in this research. Table 2 summarizes the biological data and samples collected from whales. A total of 53 research items was collected. These items are related to the studies conducted under the three main objectives of the JARPN II: study on feeding ecology of whales and marine ecosystem, pollution studies and elucidation of stock structure.

Composition of sex and sexual maturity status of common minke, sei and Bryde's whales are shown in Table 3. Statistics of body length of common minke, sei, Bryde's and sei whales is shown in Table 4. Mean body length of common minke whales was 7.39m and 6.85m for males and females, respectively. For sei whales, those were 13.16m and 14.22m for males and females, respectively. For Bryde's whales, those were 12.10m and 12.58m for males and females, respectively. For sperm whales of females, mean body length was 10.21m.

Geographical distribution of common minke, sei, Bryde's and sperm whale samples are shown in Figure 4 based on the sighting positions.

Distribution and food habits of whales

During the research period (from June to August), common minke whales fed mainly on Pacific saury (76.9%) and Japanese anchovy (23.1%) (Table 5). Sei whales were distributed widely in the offshore area. They fed mainly on copepods (45.2%) and Japanese anchovy (37.1%) (Table 5). Bryde's whales were distributed in the southern part of the research area. In this survey, Bryde's whales fed mainly on Japanese anchovy (87.9%) (Table 5). Sperm whales were also distributed widely in the research area. They fed mainly on deep sea squids.

In the 2010 summer, the Pacific saury was scarcely represented in the western North Pacific (FAJ 2010: http://www.jfa.maff.go.jp/j/press/sigen/100803.html). The low number of sightings of minke whales in summer 2010 can be explained by the scarcity of Pacific saury.

Experiments

Biopsy sampling trial
No experiment was conducted by the SSVs.

Natural marks (photo ID) for large whales
No experiment was conducted by the SSVs.

Feeding and excretion behaviour for large baleen whales
The SSVs had planned to conduct recording of the feeding and excretion behaviour of large baleen whales using photograph records. No case was observed in this research.

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Table 1. List of cetacean species and number of sightings (no. schools/no. individuals)

Sighting/sampling vessels (YS1 and YS2) and NM

Species	Primary		Secondary		Total	
	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Common minke whale	6	6	9	9	15	15
Like minke whale	0	0	2	2	2	2
Sei whale	89	148	99	185	188	333
Bryde's whale	83	110	21	26	104	136
Sperm whale	56	108	38	85	94	193
Blue whale	4	4	6	6	10	10
Fin whale	16	18	14	18	30	36
Humpback whale	5	6	0	0	5	6

Table 2. Summary of collected biological data and samples.

Research items	Common minke			Sei whale			Bryde's whale			Sperm whale		
	F	M	T	F	M	T	F	M	T	F	M	T
Body length and sex	2	12	14	57	43	100	25	25	50	3	0	3
External body proportion	2	12	14	57	43	100	25	25	50	3	0	3
Photographic recoed and external character	0	0	0	0	0	0	0	0	0	0	0	0
Diatom film recoed	0	0	0	0	0	0	0	0	0	0	0	0
Standaed measurements of blubber thickness (five points)	2	12	14	57	43	100	25	25	50	3	0	3
Detailed measurements of blubber thickness (eleven points)	0	1	1	3	2	5	2	1	3	3	0	3
Body weight	2	12	14	57	43	100	25	25	50	3	0	3
Body weight by parts	0	1	1	3	2	5	2	1	3	2	0	2
Blubber tissues for DNA study	2	12	14	57	43	100	25	25	50	3	0	3
Blubber, muscle, liver and kidney tissues for heavy metal analysis	2	12	14	57	43	100	25	25	50	3	0	3
Blubber, muscle, liver and kidney tissues for organochlorines analysis	2	12	14	57	43	100	25	25	50	3	0	3
Blubber, muscle tissues for ingredient analysis	1	3	4	3	2	5	5	0	5	0	0	0
Tissue for nutritional compornent analysis	1	3	4	3	2	5	2	3	5	0	0	0
Lung tissue for atmospheric analysis	0	5	5	0	10	10	0	10	10	3	0	3
Tissues for lipid analysis	0	0	0	0	0	0	0	0	0	0	0	0
Tissues for various analysis	2	12	14	57	43	100	25	25	50	3	0	3
Tissues for virus test	0	12	12	0	43	43	0	25	25	0	0	0
Mammary gland; lactation status, measurement and histological sample	2	0	2	57	0	57	25	0	25	3	0	3
Collection of spermaceti sample	0	0	0	0	0	0	0	0	0	0	0	0
Collection of maternal milk sample	0	0	0	4	0	4	0	0	0	1	0	1
Uterine horn; measurement and endometrium sample	2	0	2	57	0	57	25	0	25	3	0	3
Collection of ovary	2	0	2	57	0	57	25	0	25	3	0	3
Photographic record of foetus	1	0	1	35	0	35	15	0	15	1	0	1
Foetal sex (identified by visual observation)	1	0	1	35	0	35	15	0	15	1	0	1
Foetal length and weight	1	0	1	35	0	35	15	0	15	1	0	1
External measurements of foetus	1	0	1	34	0	34	15	0	15	1	0	1
Foetal blubber tissuyes for DNA study	1	0	1	35	0	35	15	0	15	1	0	1
Foetal tissues for various analysis	1	0	1	34	0	34	15	0	15	1	0	1
Foetal lens for age determination	0	0	0	33	0	33	13	0	13	1	0	1
Testis and epididymis; weight and histological sample	0	12	12	0	43	43	0	25	25	0	0	0
Collection of plasma sample	2	12	14	57	43	100	25	25	50	3	0	3
Collection of whole blood sample	0	0	0	0	0	0	0	0	0	0	0	0
Whole blood samples from umbilical coed	0	0	0	0	0	0	0	0	0	0	0	0
Plasma samples from umbilical cord	1	0	1	35	0	35	13	0	13	1	0	1
Stomach content, conventional record	2	12	14	57	43	100	25	25	50	3	0	3
Volume and weight of stomach content in each compartment	0	0	0	0	0	0	0	0	0	0	0	0
Stomach contents for feeding study	2	12	14	44	28	72	25	25	50	3	0	3
Record of external parasites	2	12	14	57	43	100	25	25	50	3	0	3
Collection of external parasites	1	0	1	0	1	1	0	0	0	1	0	1
Record of internal parasites	0	0	0	0	0	0	0	0	0	0	0	0
Collection of internal parasites	0	0	0	0	0	0	0	0	0	0	0	0
Earplug for age determination	2	12	14	57	43	100	25	25	50	0	0	0
Tympanic bulla for age determination	0	1	1	3	2	5	2	1	3	0	0	0
Maxillally teeth for age determination	0	0	0	0	0	0	0	0	0	0	0	0
Lens for age determination	2	12	14	56	42	98	25	25	50	2	0	2
Largest baleen plate for morphologic study and age determination	2	12	14	57	43	100	25	25	50	0	0	0
Baleen plate measurements (length and breadth)	0	0	0	0	0	0	0	0	0	0	0	0
Length of each baleen plate series	2	12	14	0	0	0	0	0	0	0	0	0
Vertebral epiphyses sample	2	12	14	57	43	100	25	25	50	3	0	3
Number of vertebrae	0	0	0	3	2	5	2	1	3	3	0	3
Number of ribs	0	0	0	0	0	0	0	0	0	0	0	0
Brain weight	0	1	1	3	2	5	2	1	3	2	0	2
Skull measurements (length and breadth)	2	11	13	56	42	98	25	25	50	3	0	3

*: Including fetus of sex unknown.

Table 3. Composition of sex and sexual maturity status of samples collected during 2010 JARPN II.

Species	Sub area	Male				Female								Total
							Mat.							
		Imm.	Mat.	Uk	Total	Imm.	Ovu.	Rest.	Preg.	Lact.	Preg. Lact.	Total	Total	
Common minke	SA7	0	0	0	0	0	0	0	0	0	0	0	0	0
	SA8	0	0	0	0	0	0	0	0	0	0	0	0	0
	SA9	2	9	1	12	1	0	0	1	0	0	1	2	14
	Combined	2	9	1	12	1	0	0	1	0	0	1	2	14
Sei	SA7	1	4	0	5	1	0	1	3	0	0	4	5	10
	SA8	3	3	0	6	3	0	2	4	0	0	6	9	15
	SA9	11	21	0	32	6	1	4	28	4	0	37	43	75
	Combined	15	28	0	43	10	1	7	35	4	0	47	57	100
Bryde's	SA7	0	0	0	0	0	0	0	1	0	0	1	1	1
	SA8	0	0	0	0	0	0	0	0	0	0	0	0	0
	SA9	5	19	1	25	4	1	5	14	0	0	20	24	49
	Combined	5	19	1	25	4	1	5	15	0	0	21	25	50
Sperm	SA7	0	0	0	0	0	0	0	0	0	0	0	0	0
	SA8	0	0	0	0	1	0	0	1	1	0	2	3	3
	SA9	0	0	0	0	0	0	0	0	0	0	0	0	0
	Combined	0	0	0	0	1	0	0	1	1	0	2	3	3

Table 4. Body length (m) of samples collected during 2010 JARPN II.

Species	Sub area	Male					Female				
		n	mean	S.D.	min	max	n	mean	S.D.	min	max
Common minke	SA7	0	-	-	-	-	0	-	-	-	-
	SA8	0	-	-	-	-	0	-	-	-	-
	SA9	12	7.39	0.75	5.63	8.00	2	6.85	2.76	4.90	8.80
	Combined	12	7.39	0.75	5.63	8.00	2	6.85	2.76	4.90	8.80
Sei	SA7	5	13.41	0.43	12.66	13.76	5	13.90	0.91	12.90	15.31
	SA8	6	13.09	0.70	12.44	14.32	9	13.80	0.81	12.61	15.32
	SA9	32	13.13	1.00	10.52	14.23	43	14.35	0.99	11.14	16.14
	Combined	43	13.16	0.91	10.52	14.32	57	14.22	0.97	11.14	16.14
Bryde's	SA7	0	-	-	-	-	1	13.92	-	13.92	13.92
	SA8	0	-	-	-	-	0	-	-	-	-
	SA9	25	12.10	1.02	9.08	13.21	24	12.53	0.85	10.54	13.78
	Combined	25	12.10	1.02	9.08	13.21	25	12.58	0.88	10.54	13.92
Sperm	SA7	0	-	-	-	-	0	-	-	-	-
	SA8	0	-	-	-	-	3	10.21	0.98	9.42	11.30
	SA9	0	-	-	-	-	0	-	-	-	-
	Combined	0	-	-	-	-	3	10.21	0.98	9.42	11.30

Table 5. Dominant prey species and stomach contents weight (1st. + 2nd. stomachs) found in each baleen whale species.

Dominant prey species			N	Range of weight (kg)		
Common minke whale						
	Fish	Japanese anchovy	3	0.3	-	23.4
		Pacific saury	10	15.0	-	49.6
Sei whale						
	Krill		2	0.9	-	17.1
	Copepods	Neocalanus spp.	28	0.2	-	293.9
	Fish	Japanese anchovy	23	0.4	-	236.8
		Pacific saury	8	1.0	-	80.9
		Spotted chub mackere	1		27.44	
Bryde's whale						
	Krill		4	1.9	-	107.8
	Fish	Japanese anchovy	29	0.2	-	662.2

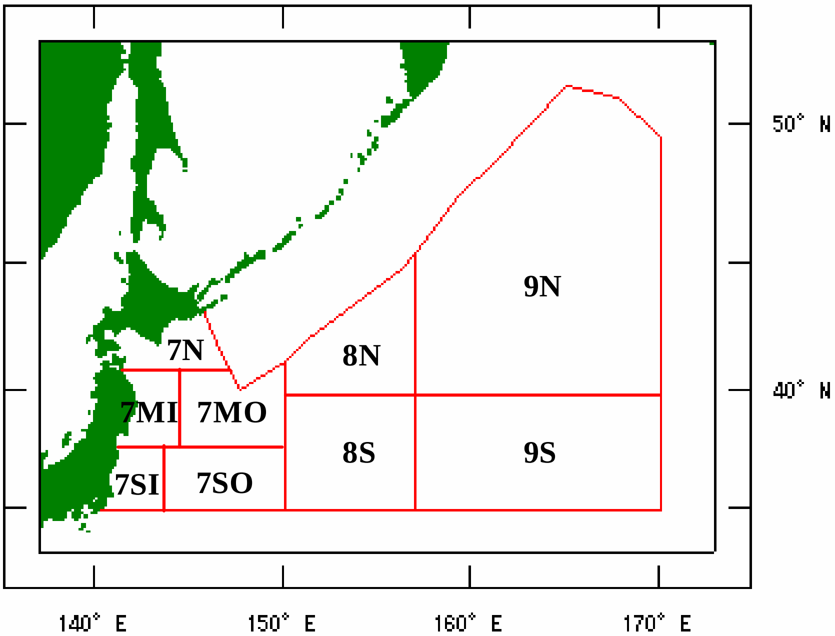

Fig 1. Map showing the research area and strata of the JARPN II full-scale program.

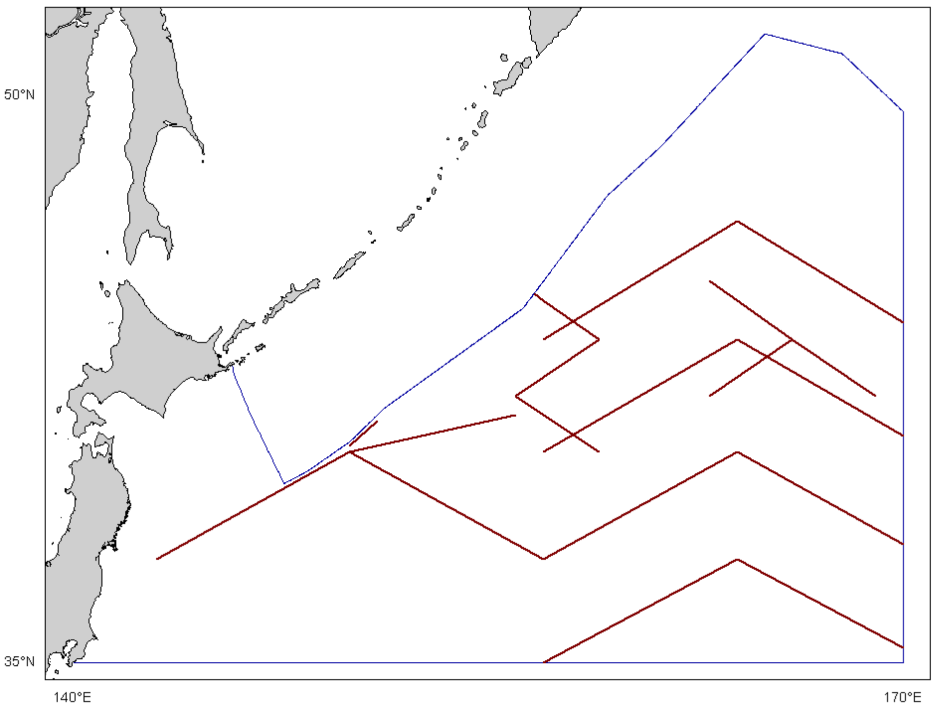

Fig. 2. Track-line set of the sighting/sampling vessels (SSVs).

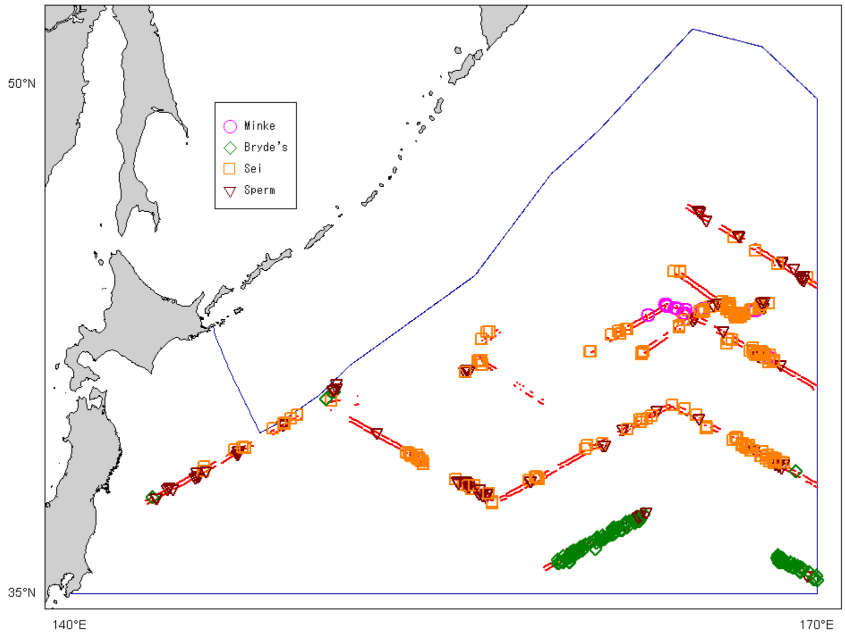

Fig. 3. The positions of the sightings of common minke whale (pink circle), sei (orange square), Bryde's (green diamond) and sperm (brown triangle) whales by the two sighting/sampling vessels (SSVs)

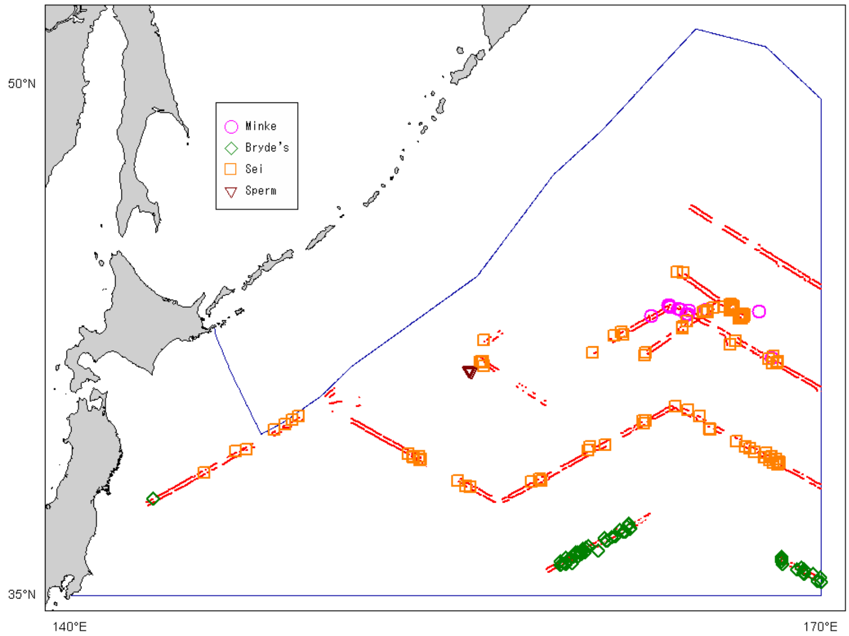

Fig. 4. The Sighting positions of the sampled common minke whale (pink circle), sei (orange square), Bryde's (green diamond) and sperm (brown triangle) whales. Two blocks show the cooperative survey areas of prey species and whale sampling survey.

Appendix 1

Cruise report of whale sighting and whale prey species surveys in the offshore region of the western North Pacific in 2010

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ABSTRACT

Whale sighting and whale prey species surveys in the subarctic and transition regions of the western North Pacific were conducted in July and August 2010 by R/V Hokko Maru of Hokkaido National Research Institute of Fisheries Science. The objective of these surveys in this year are to examine habitat and prey preference of sei whale, hence these surveys were cooperated with the sampling survey of the whale by Nisshin Maru and two sampling vessels under JARPN II program. The distribution, abundance, and size composition of the whale prey species were investigated with the midwater trawl, MOHT, twin NORPAC nets, and quantitative echosounders during the daylight period. Sei whale was densely distributed in the subarctic boundary where euphausiids were abundantly distributed at 100–200 m, and also in the subarctic frontal zone where was the main habitat of Japanese anchovy and Japanese sardine. Because relative abundance of euphausiids and/or these two small epipelagic fish species seemed to be significantly higher in the main distribution area than its adjacent area of the whale, sei whale seems to select prey rich environment as their main habitat. The information would be useful to establish the effective method of dedicated sighting survey for the whale and also establish suitable extrapolation method of whale abundance in the area where sighting survey was not conducted. Prey preference of the whale, which is important in relation to establish ecosystem models, will be investigated by comparing the data of prey environment and stomach content composition of the whale.

KEY WORDS: SEI WHALE, HABITAT SELECTION, PREY PREFERENCE, WHAKE SIGHTING SURVEY, PREY SPECIES SURVEY, OFFSHORE REGION, WESTERN NORTH PACIFIC

INTRODUCTION

Sei whale *Balaenoptera borealis* is the abundant baleen whale in the western North Pacific and migrates into high latitudinal area mainly between 40 and 47˚N during spring and summer from the low latitudinal wintering area (Kasamatsu *et al*. 2009). Previous studies have indicated that these whales frequently feed on small epipelagic fish species such as Japanese sardine *Saldinops melanostictus*, Japanese anchovy *Engraulis japonicus*, and/or Pacific saury *Cololabis saira* in summer, suggesting the competition between whale and fisheries (Nemoto 1962, Kawamura 1973, Tamura *et al*. 1998, Tamura and Fujise 2002, Konishi *et al*. 2009). Subarctic copepods such as *Neocalanus cristatus* and *N. plumchrus*, and euphausiids are also sometimes important prey for sei whale (Nemoto 1962, Konishi *et al*. 2009). However, quantitative data on the distribution patterns and feeding habits of these whales in relation to oceanographic conditions and prey environment are extremely limited. Such information is essential to estimate feeding impact of the whale on commercially important small epipelagic fish species and also to estimate prey preference of the whale, which are important to establish ecosystem models for multi-species management. Furthermore, these knowledge are also important to estimate abundance of the whale more accurately, which is related to single species management of the whale, because extrapolation method of whale abundance in the area where sighting survey is not conducted could be established based on the data of habitat preference of the whale. In this document, we mainly reported habitat preference of sei whale in relation to oceanographic and prey environments. Information on prey preference of sei whales will be obtained by comparing the prey environment data with stomach content data of the whale in the future.

Previously, our survey had been conducted to obtain the data of only oceanographic conditions and abundance of prey species in the environment to estimate prey preference of the whale. However, knowledge on habitat selection of each whale species is extremely restricted due to lack of quantitative data on their distributions. Therefore, we newly added whale sighting survey in our research program in this year. We also newly started several surveys or experiments like measurements of sound speed and density contrasts for major zooplankton preys such as copepods and euphausiids to estimate abundance of each prey species more accurately based on acoustic data (see below).

MATERIALS AND METHODS

Whale sighting and whale prey species surveys were conducted in the western North Pacific enclosed by latitude from 41˚N to 45º30'N and longitude from 156ºE and 163ºE excluding Russian EEZ from 21 July to 10 August 2010 by the trawler–type research vessel, *Hokko Maru* (1246 GT, Hokkaido National Research Institute of Fisheries Science, Fig. 1). This vessel equips 200 kHz echo sounder as was shown below, which is essential to estimate abundance of meso–zooplankton like copepods based on acoustic data. The waypoints of predetermined track lines are shown in Table 1. These surveys by Hokko Maru and whale sampling survey by Nisshin Maru and two sampling vessels under the JARPN II program were conducted concurrently at the same area within 15 hours per day. All surveys were conducted during the daylight period from one hour after sunrise to one hour before sunset (usually from 03:30 to 17:50 in JST).

Whale sighting survey was conducted along with echosounder survey (see below) basically in passing mode when wind velocity was less than 10 knots and visibility was more than two nautical miles. However, abeam closing survey was also conducted within two nautical miles perpendicular to track line in case that the species of baleen whale could not identified by passing mode. During the survey, two primary observers were allocated to the upper bridge.

A Conductivity–Temperature–Depth (CTD, Sea–Bird Co., Ltd.) profiler cast was made down to 500 m depth at each sampling station to determine the position of the subarctic boundary and subarctic front. Distribution and abundance of the prey species were investigated with midwater trawl, Matsuda–Oozeki–Hu–Trawl (MOHT, Oozeki *et al*. 2004), Vertical Multiple Plankton Sampler (VMPS, Tsurumi Seiki Co., Ltd), twin North Pacific Standard (NORPAC) nets, and quantitative echosounder on the track lines as follows (Fig. 2). In this year, we newly conducted the towing survey of each deep scattering layer (DSL) to estimate abundance of prey species, especially copepods and euphausiids, more accurately by acoustic survey. This information is also essential to estimate feeding depth range of the whale, which is badly needed to estimate prey environment of the whale.

Midwater trawl sampling

The midwater trawl adopted in this study had a mouth opening of approximately 30 x 30 m with a 17.5 mm liner cod end. The sampling depths and the height of the net mouth were monitored by net monitor system (PI32, SIMRAD). In this survey, trawls were made to identify species and size compositions of acoustic backscatters in the echosounders and also aimed for collecting data on species difficult to detect by the echosounders such as squids and neustonic organisms like Pacific saury. Trawling station was predetermined at generally every 20 to 30 nautical mile apart on the track lines. At each predetermined station, a trawl net was towed at 0–30 m for 60 minutes (Table 2). Towing speed was 3–4 knots. All samples were identified to the lowest taxonomic level possible and wet body weight of each species was measured aboard the ship. For the major species, individual body length was measured from randomly selected 100 samples. When sample size was less than 100 individuals, body length was measured for all. We also measured the total wet weight of these samples to estimate the total catch number for each sampling.

MOHT sampling

We firstly used MOHT to examine species and size compositions and vertical distribution patterns of macro–zooplanktons, especially euphausiids (Table 2). The mouth opening and mesh size of this net were

5.06 m^2 and 2.0 x 2.0 mm, respectively. MOHT was towed at about 2 knots in the target depths for 10 to 40 minutes. We selected target depths using information of DSL in the echograms of 38, 120, and 200 kHz. Samples were preserved in 5 % formalin–buffered seawater for later analysis in the laboratory.

VMPS sampling

This is the first time to use VMPS in this survey. VMPS sampling was adopted to examine vertical distribution and abundance of meso–zooplankton, especially copepods. The mouth opening and mesh size of the net were 0.25 m^2 and 0.01 x 0.01 mm, respectively. VMPS was towed vertically in three target depths per one cast (Table 3). Target depths were selected by DSL patterns of each sampling position. The volume of seawater filtered by each net was measured with a flow meter mounted at the net mouth. Samples were preserved in 5 % formalin–buffered seawater for later analysis in the laboratory.

Twin NORPAC net sampling

We conducted twin NORPAC net samplings in the 0–150 m layer at all stations to collect data for abundance of micro– and meso–zooplanktons, especially copepods, in the epipelagic zone. The mouth opening of this net was 0.15 m^2 and the mesh sizes of the net were 0.11 x 0.11 mm and 0.33 x 0.33 mm. A flow meter was attached to each net to measure the volume of seawater filtered. Samples were preserved in 5 % formalin–buffered seawater.

Quantitative echosounder survey

We collected acoustic data by quantitative echsounders, SIMRAD ER60 with operating frequency at 38, 70, 120, and 200 kHz and SIMRAD ES60 with 12 kHz, by steaming at 10 knots on the track lines. Calibrations were carried out in the coastal region off Shiranuka (42˚53'N, 144˚10'E) on 9 to 10 August using a standard sphere technique. A tungsten carbide sphere (38.1 mm in diameter) was used as the standard sphere. Acoustic data will be analyzed with an aid of SonarData Echoview (Sonar Data Co., Ltd.) software.

Other surveys

The following surveys were firstly adopted in our research program. Micropro (Salantic) and Chlorotec (JFE advance) surveys were conducted in the 0–150 m layer to obtain data on vertical distribution of illumination and primary production, respectively, in each sampling area. The former data will be analysed in relation to vertical distribution and/or migration of DSL to estimate vertical distribution of each zooplankton prey and also to estimate species composition of each DSL. Japanese Quantitative Echo sounder and Stereo video camera system (J–QUEST, Sawada *et al*. 2004, 2009) survey was conducted to obtain target strength in relation to tilt angle of Japanese anchovy and to identify the species of the scattering layer interested in the echograms, which are essential to estimate abundance of these prey species more accurately based on acoustic data. Furthermore, two living copepod species, *N. cristatus* and *N. plumchrus*, and living euphausiids mainly *Euphausia pacifica*, were sorted and sound speed and density contrasts of each species were measured by time of flight method and density bottle method, respectively (Mikami *et al.* 2000). These experiments are important in relation to obtain theoretical values of target strength of these species, which are essential to estimate abundance of these preys by acoustic data.

RESULTS AND DISCUSSION

A total of 12 midwater trawl surveys, 10 MOHT surveys, 12 VMPS surveys, 20 NORPAC surveys, and four J–QUEST surveys were conducted (Tables 3 to 6). Sound speed and density contrasts of zooplanktons were measured nine times for copepods and three times for euphausiids (Tables 7 and 8). While most of these analyses, together with Micropro and Chlorotec analyses are currently underway, the preliminary results are as follows.

In this study area, two oceanographic fronts, subarctic front between subarctic region and transitional domain, and subarctic boundary between transitional domain and transition zone are distributed (Favorite *et al*. 1976, Pearcy 1991). According to Kawai (1972) and Murakami (1994), subarctic front is defined by a water temperature lower than 5˚C at 100 m. Sub arctic boundary is defined by 34.0 PSU salinity front in the epipelagic zone (Favorite *et al*. 1976). In the western survey area, subarctic boundary and subarctic front was located between 41 and 42˚N and 44 and 45˚N, respectively (Fig. 3). In the eastern survey area, salinity in the epipelagic zone was > 34.0 PSU, indicating that this area was located north of subarctic boundary. In this area, water temperature at 100 m was less than 5˚C except for the area north of 45˚N. However, water mass warmer than 5˚C was found at 150-200 m layer south of 43˚N and between 44˚30' and 45˚N, suggesting that these areas were located in the transitional domain. Therefore we deemed subarctic front to be located at both between 43 and 44˚N and 44 and 45˚N (Fig. 3).

A total of 358 nautical miles was searched. A total of 26 animals of 21 schools (five baleen whale species and sperm whale) were found by primary sighting (Table 9). Of these, sei whale was the most abundant in the baleen whale community of this study area.

''Hot spot'' of sei whale was found in the region around subarctic boundary and subarctic front (Fig. 4). The result of our survey indicated that euphausiids were significantly abundant in the subarctic boundary than in the normal transition zone and the transitional domain and abundance of Japanese anchovy and Japanese sardine was significantly higher in the subarctic frontal zone than in the normal transitional domain and the subarctic region (Figs. 5 and 6). Therefore, sei whale might select prey rich area as their main habitat. This probably indicates that main distribution of sei whale could be estimated using information of oceanographic features. When sighting survey was mainly conducted in such areas, abundance of the whale could be estimated more accurately and also more effectively.

Sound speed contrasts of copepods and euphausiids were ranged from 1.012 to 1.034 (n = 7) and from 1.026 to 1.035 (n = 3), respectively, and density contrast was 0.993–1.005 (n = 58) for copepods and 1.038–1.055 (n = 20) for euphausiids (Tables 7 and 8). Sound speed contrast tended to decrease with increasing temperature for both copepods and euphausiids, indicating that information of habitat temperature is indispensable to estimate biomass of these zooplanktons by acoustic data (Table 7).

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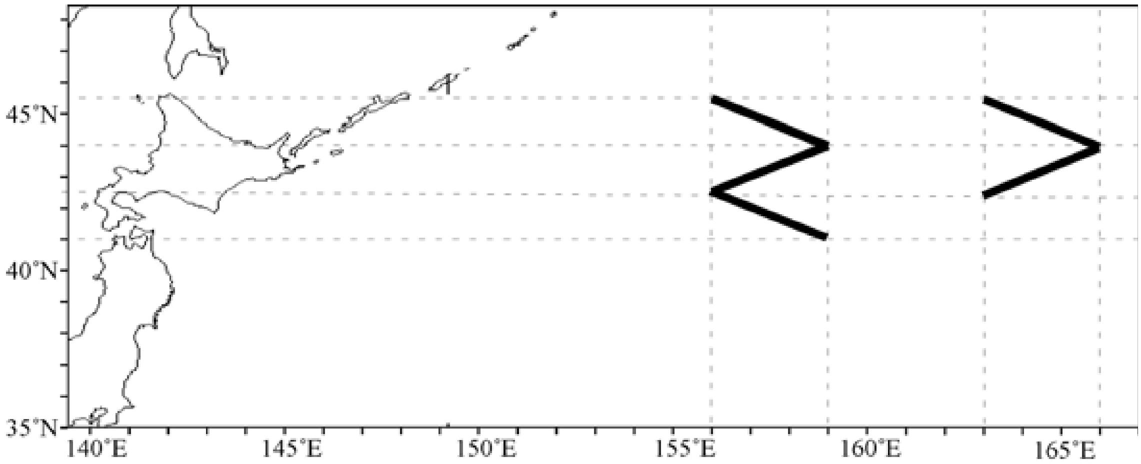

Fig. 1. Research area and track lines of whale sighting and whale prey species surveys in July-August 2010.

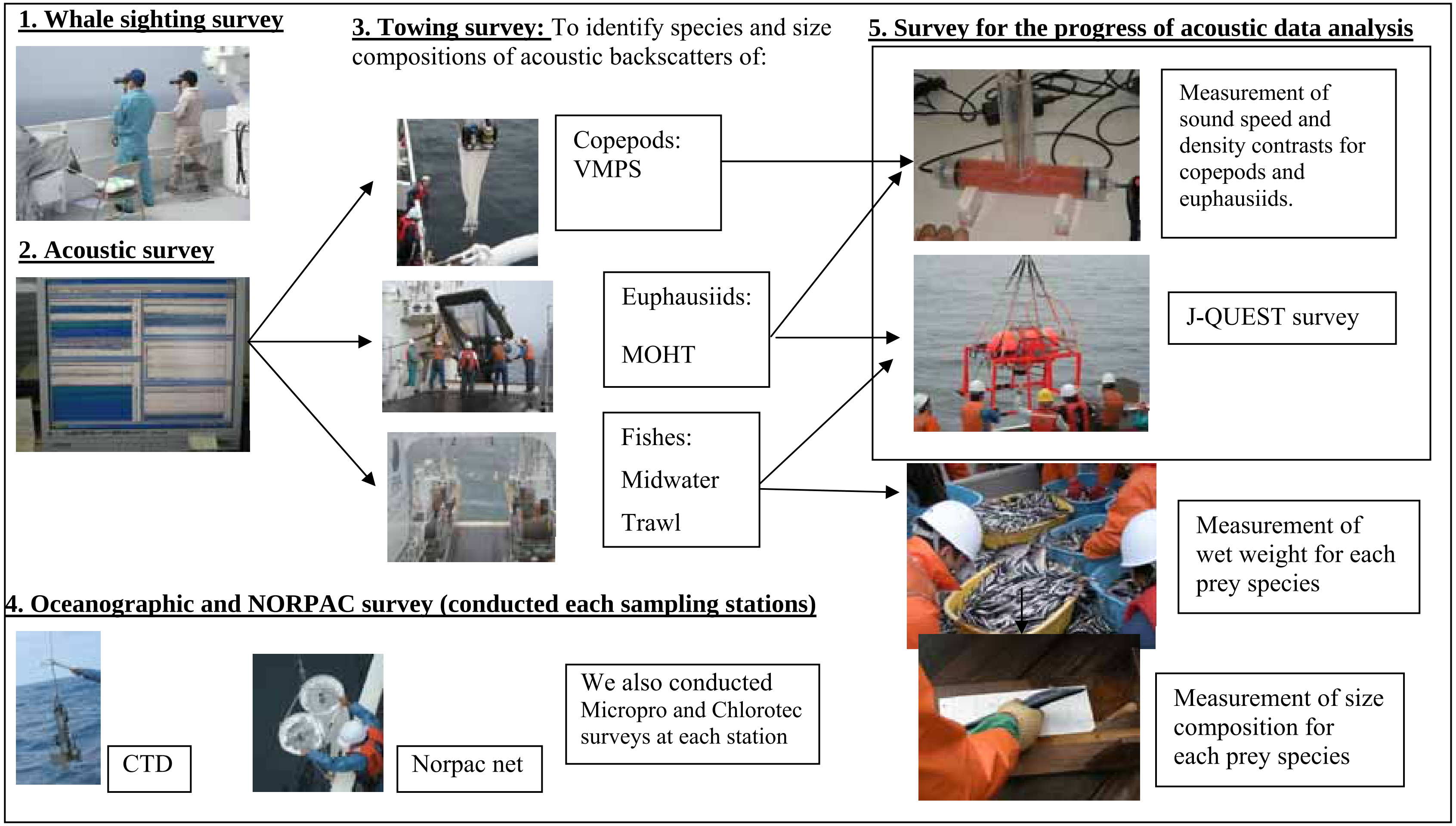

Fig. 2. Survey method

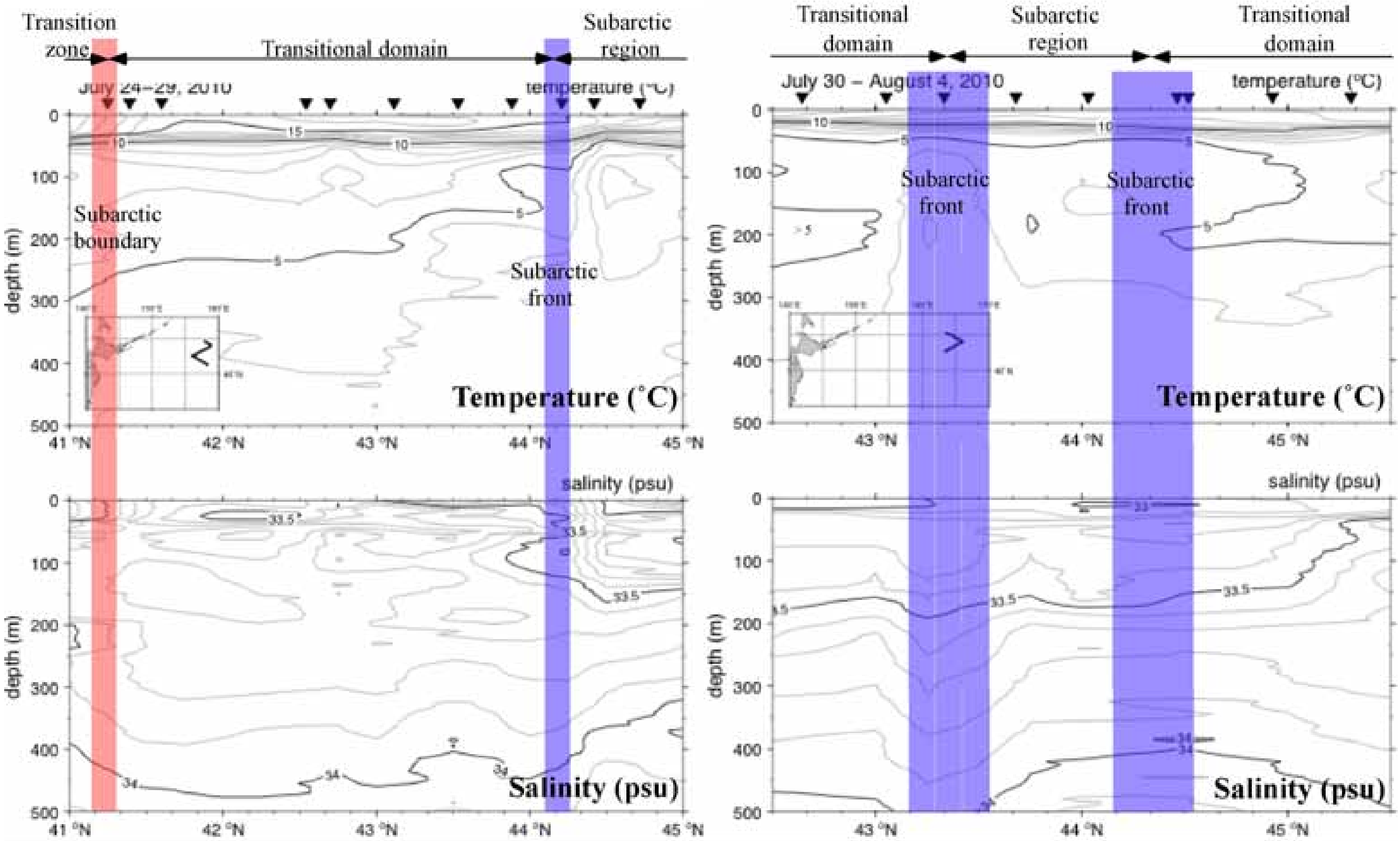

Fig. 3. Vertical temperature and salinity profiles along with the eastern (left) and western (right) track lines.

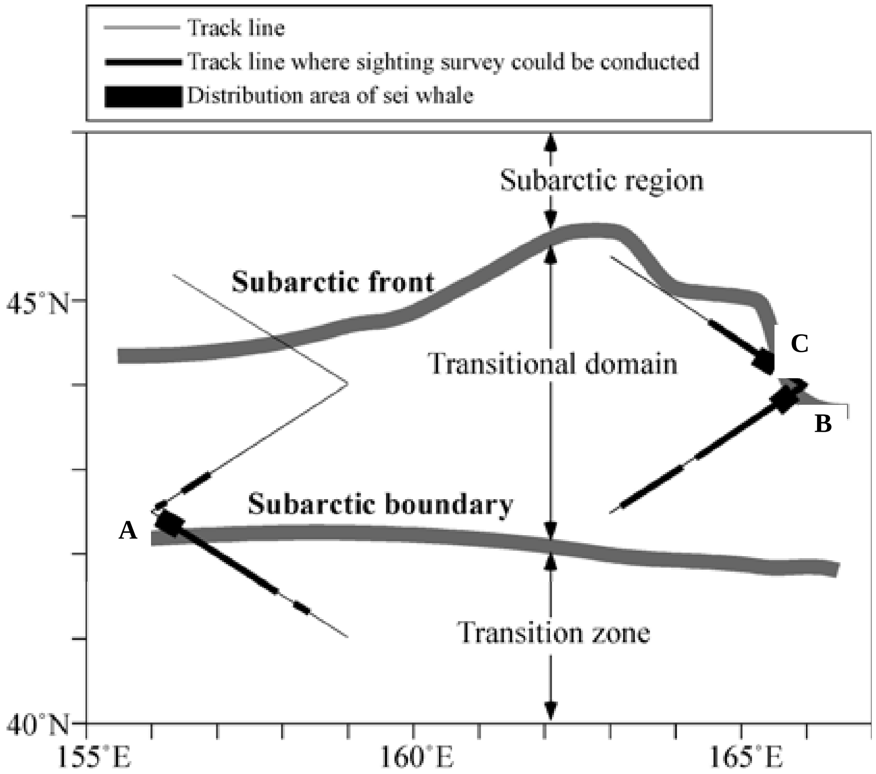

Fig. 4. Distributions of two oceanographic fronts and sighting positions of sei whale in July-August 2010.

Results of primary sighting indicated that 4 animals of 3 schools, 5 animals of 4 schools, and 4 animals of 3 schools of sei whales were distributed at the areas A, B, and C, respectively.

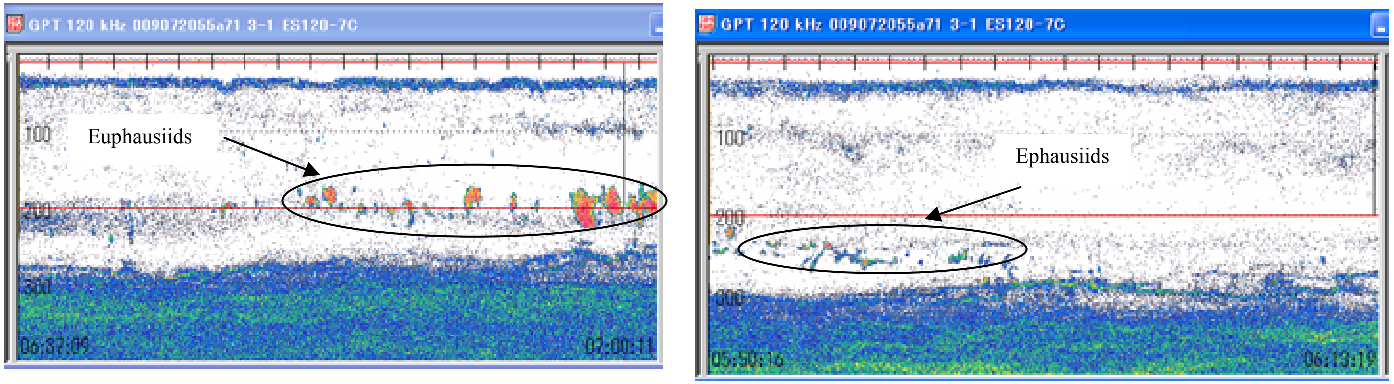

Fig. 5. Typical ecogram in the subarctic boundary where sei whales were densely distributed (left), and in the northern and southern region of subarctic boundary (right). Euphausiids was more abundantly distributed in the former region than in the latter region.

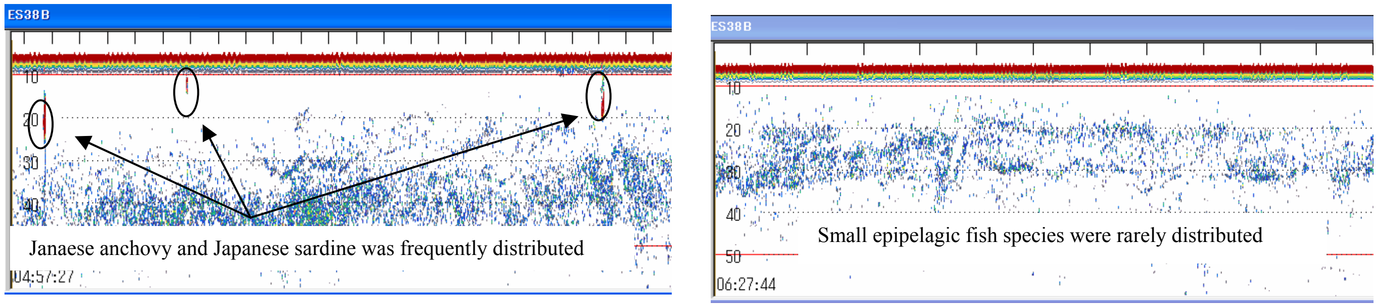

Fig. 6. Typical ecogram in the subarctic frontal zone where sei whales were densely distributed (left), and in the northern and southern region of the front (right). Small epipelagic fish species such as Japanese anchovy and Japanese sardine was frequently and rarely distributed in the former and the latter regions, respectively.

Table 1. Waypoints of track lines.

WP	Latitude (N)	Lingitude (E)
501	41-00.0	159-00.0
503	42-30.0	156-00.0
505	44-00.0	159-00.0
507	45-40.0	156-40.0
521	42-30.0	163-00.0
522	44-00.0	166-00.0
523	45-30.0	163-00.0

Table 2. Sampling data of midwater trawl surveys. 0.0: CPUE < 0.1 kg.

					Latitude			Longitude			Sampling depth (m)		Sampling	CPUE (kg/h)								
Stn	Year	Month	Day	SST (ūC)	Degree	Minute	N/S	Degree	Minute	E/W	Shallowest	Deepest	duration (min)	Japanese anchovy	Japanese sardine	Common mackerel	Pacific saury	Coho salmon	Chum salmon	Pacific pomfret	Other fishes	Common squid
1	2010	7	24	17.9	41	11.1	N	158	38.4	E	0	30	60									
5	2010	7	26	16.6	42	37.0	N	156	14.6	E	0	30	60	37.2	12.4	0.9	13.1			3.8		24.4
7	2010	7	27	15.7	43	27.3	N	157	54.5	E	0	30	60	42.1	9.5	0.4				4.0	2.2	7.3
8	2010	7	28	15.4	43	49.3	N	158	38.6	E	0	30	60	138.0	5.2	1.5				1.9		1.7
9	2010	7	28	15.3	44	10.8	N	158	40.2	E	0	30	60	2.6	0.0							0.8
11	2010	7	29	13.6	44	37.4	N	157	46.0	E	0	30	60				236.4		7.1	50.3		0.1
13	2010	7	31	13.9	42	59.0	N	163	57.7	E	0	30	60	26.9	0.0		10.2			161.6		0.0
15	2010	8	1	13.3	43	36.0	N	165	11.5	E	0	30	60	2.8	0.0	1.0		1.5		11.7		
16	2010	8	2	12.7	43	57.3	N	165	54.6	E	0	30	60				234.4		2.3			
17	2010	8	2	12.4	44	21.8	N	165	12.2	E	0	30	60		0.0		46.6		11.4	26.9		
19	2010	8	3	13	44	49.9	N	164	23.3	E	0	30	60	348.7	15.3	14.5	2.0		10.1	45.7		
20	2010	8	4	13.1	45	18.9	N	163	23.4	E	0	30	60				3.8			13.4		

Table 3. Sampling data of MOHT surveys.

				SST	Latitude			Longitude			Target	Sampling duration at	Main	
Stn	Year	Month	Day	(ūC)	Degree	Minute	N/S	Degree	Minute	E/W	depth (m)	the target depth (min)	catch	Remarks
2	2010	7	24	17.9	41	25.8	N	158	9.6	E	170	18	Euphausiids	
3	2010	7	25	15.2	41	38.6	N	157	43.4	E	200	41	Euphausiids	
4	2010	7	26	16.3	42	34.0	N	156	7.4	E	50	30	Copepods	
6	2010	7	27	15.8	43	9.0	N	157	17.5	E	210	27	Euphausiids	
10	2010	7	29	13.0	44	30.9	N	157	58.5	E	220	9	Copepods	
10	2010	7	29	13.0	44	30.9	N	157	58.5	E	300	25	Euphausiids	
12	2010	7	31	14.2	42	42.0	N	163	23.7	E	45	30	Copepods	
12	2010	7	31	14.1	42	40.2	N	163	20.4	E	120	25	Copepods	
14	2010	8	1	13.3	43	22.0	N	164	44.1	E	275	15	Copepods	
18	2010	8	3	13	44	32.4	N	164	55.2	E	0 to 300	-	Copepods	Oblique tow

Table 4. Sampling data of VMPS surveys.

				SST	Latitude			Longitude			Sampling depth (m)		Flow meter
Stn	Year	Month	Day	(ūC)	Degree	Minute	N/S	Degree	Minute	E/W	Shallowest	Deepest	count
4	2010	7	26	16.3	42	34.0	N	156	7.4	E	0	250	30
											200	250	24
											100	200	46
											30	100	32
6	2010	7	27	15.8	43	9.0	N	157	17.5	E	0	270	21
											240	270	44
											130	240	40
											39	130	14
8	2010	7	28	15.4	43	49.3	N	158	38.6	E	0	240	51
											160	240	38
											65	160	39
											25	65	22
11	2010	7	29	13.6	42	25.3	N	156	10.7	E	0	330	41
											253	330	27
											144	253	43
											55	144	38
11	2010	7	29	13.6	44	25.5	N	156	10.8	E	0	70	8
											50	70	9
											36	50	6
											19	36	7
12	2010	7	31	14.2	42	38.6	N	163	16.7	E	0	280	14
											260	280	8
											150	260	40
											70	150	31
12	2010	7	31	14.2	42	38.6	N	163	16.7	E	0	70	4
											40	70	11
											10	40	12
											0	10	4
14	2010	8	1	13.3	43	22.2	N	164	44.4	E	0	275	9
											240	275	16
											200	240	13
											50	200	68
14	2010	8	1	13.3	43	22.2	N	164	44.4	E	0	50	2
											24	50	9
											10	24	6
											0	10	5
16	2010	8	2	12.7	44	18.6	N	166	5.2	E	0	85	3
											58	85	12
											20	58	13
											0	20	7
18	2010	8	3	13	44	32.4	N	164	55.2	E	0	150	15
											65	150	31
											23	65	16
											5	23	7
20	2010	8	4	13.1	45	18.9	N	163	23.4	E	0	322	28
											228	322	52
											54	228	95
											29	54	15

Table 5. Sampling data of NORPAC net surveys.

				SST	Latitude			Longitude			Sampling depth (m)		Flow meter count	
Stn	Year	Month	Day	(ūC)	Degree	Minute	N/S	Degree	Minute	E/W	Shallowest	Deepest	XX13	GG54
1	2010	7	24	17.9	41	11.1	N	158	38.4	E	0	150	1440	1418
2	2010	7	24	17.9	41	25.8	N	158	9.6	E	0	150	1525	1530
3	2010	7	25	15.2	41	38.6	N	157	43.4	E	0	150	1583	1560
4	2010	7	26	16.3	42	34.0	N	156	7.4	E	0	150	1550	1582
5	2010	7	26	16.6	42	37.0	N	156	14.6	E	0	150	1682	1660
6	2010	7	27	15.8	43	9.0	N	157	17.5	E	0	150	1463	1560
7	2010	7	27	15.7	43	27.3	N	157	54.5	E	0	150	1463	1660
8	2010	7	28	15.4	43	49.3	N	158	38.6	E	0	150	1540	1600
9	2010	7	28	15.3	44	10.8	N	158	40.2	E	0	150	1440	1525
10	2010	7	29	13.0	44	30.9	N	157	58.5	E	0	150	1435	1475
11	2010	7	29	13.6	44	37.4	N	157	46.0	E	0	150	1590	1545
12	2010	7	31	14.2	42	42.0	N	163	23.7	E	0	150	1445	1482
13	2010	7	31	13.9	42	59.0	N	163	57.7	E	0	150	1529	1518
14	2010	8	1	13.3	43	22.0	N	164	44.1	E	0	150	1440	1448
15	2010	8	1	13.3	43	36.0	N	165	11.5	E	0	150	1473	1488
16	2010	8	2	12.7	43	57.3	N	165	54.6	E	0	150	1570	1587
17	2010	8	2	12.4	44	21.8	N	165	12.2	E	0	150	1520	1582
18	2010	8	3	13	44	32.4	N	164	55.2	E	0	150	1472	1485
19	2010	8	3	13	44	49.9	N	164	23.3	E	0	150	1488	1536
20	2010	8	4	13.1	45	18.9	N	163	23.4	E	0	150	1523	1565

Table 6. Survey data of J-QUEST cast.

				SST	Latitude			Longitude				
Stn	Year	Month	Day	(ūC)	Degree	Minute	N/S	Degree	Minute	E/W	Target depth (m)	Target animals
2	2010	7	24	17.9	41	25.8	N	158	9.6	E	160 and 349	Copepods, euphausiids
4	2010	7	26	16.3	42	34.0	N	156	7.4	E	5, 10, 20, and 50	Copepods, euphausiids
14	2010	8	1	13.3	43	22.0	N	164	44.1	E	30, 40, and 260	Copepods, euphausiids
21	2010	8	5 to 6	17.3	44	18.732	N	159	22.4	E	20	Japanese anchovy

Table 7. Data of sound speed contrasts for each zooplankton species obtained by Hokko Maru cruise in 2010.

Date	Species	ID	St.	Sampling gyer	Volume fraction of Euphausiids and Copepods[%]	Temperature [℃]	Sound speed contrast
20100725	Copepods	Cope001	3	MOHT 1st	30	5.8-11.8	1.0267-1.0342
20100727	Euphausiids	OKI001	6	MOHT 1st	45	7.6-11.9	1.0304-1.0324
	Euphausiids	OKI002	6	MOHT_1st	48	7.3-11.8	1.0255-1.0293
20100729	Euphausiids	OKI003	10	MOHT 2nd	42	9.4-11.7	1.0318-1.0351
20100731	Copepods	Cope002	12	MOHT_1st	54	9.0-11.8	1.0129-1.0143
	Copepods	Cope003	12	MOHT 1st	31	6.5-11.7	1.0122-1.0181
	Copepods	Cope004	12	MOHT 1st	44	5.6-12.0	1.0120-1.0185
	Copepods	Cope005	12	MOHT 1st	34	4.5-12.0	1.0135-1.0177
20100801	Copepods	Cope006	14	MOHT 1st	36	1.9-11.8	1.0141-1.0241
20100802	Copepods	Cope007	16	NORPAC	-	-	-
	Copepods	Cope008	17	NORPAC	35	6.1-11.9	1.0141-1.0213
20100803	Copepods	Cope009	18	NORPAC	4	4.5-11.8	1.0259-1.0657

Table 8. Data of density contrasts for each zooplankton species obtained by Hokko Maru cruise in 2010.
TL: Total length; PL Prosome length; CL: Carapace length; AB: Length of sixth abdominal segment.

Sampring date	St.	Sampring gyer	Species	ID	TL or PL [mm]	CL[mm]	AB[mm]	Body height [mm]	Body width [mm]	Density contrast	Measurement date
20100725	3	MOHT	Copepods	Cope001	6.78			1.92	2.07	0.9991	20100725
				Cope022	6.46			1.63	2.07	0.9960	20100807
				Cope023	6.5			1.82	1.82	0.9961	
				Cope024	6.5			1.75	1.97	0.9976	
				Cope025	6.7			1.77	1.95	0.9986	
				Cope026	6.7			1.77	1.97	0.9986	
				Cope027	6.34			1.77	1.92	0.9987	
				Cope052	6.7			1.53	2.02	1.0000	20100808
				Cope053	6.74			1.77	1.95	0.9982	
				Cope054	6.3			1.58	1.87	1.0000	
20100727	6	MOHT	Euphausiids	OKI001	10.48	3.1	1.48	1.03	1.08	1.0519	20100727
				OKI002	12.56	3.64	1.82	1.33	1.38	1.0452	
				OKI003	10.56	2.95	1.53	0.96	1.08	1.0452	
				OKI004	12.72	3.55	1.75	1.21	1.28	1.0472	
				OKI005	11.36	3.18	1.72	0.98	1.23	1.0482	
				OKI006	12.8	3.57	1.82	1.23	1.33	1.0490	
				OKI017	10.24	3	1.58	0.89	1.03	1.0529	20100730
				OKI018	10.4	3.05	1.48	0.89	1.03	1.0501	
				OKI019	10.43	3	1.53	0.94	1.03	1.0551	
				OKI020	12.16	3.59	1.77	1.18	1.28	1.0460	
20100729	10	MOHT	Euphausiids	OKI007	20.08	5.54	2.17	1.58	1.48	1.0511	20100729
				OKI008	21.6	6.54	3.1	2.24	2.31	1.0403	
				OKI009	20.4	6.06	2.98	2.17	2.27	1.0512	
				OKI010	13.6	3.82	1.92	1.28	1.4	1.0447	
				OKI011	20.88	6.2	3	2.12	2.12	1.0382	
				OKI012	20.4	6.08	2.91	2.07	2.22	1.0426	
				OKI013	20.16	6.06	2.81	1.97	2.24	1.0470	20100730
				OKI014	20.08	5.98	2.91	2.04	2.02	1.0449	
				OKI015	21.52	6.26	3.05	2.22	2.31	1.0405	
				OKI016	19.36	5.83	2.91	2.07	2.02	1.0418	
20100731	12	MOHT_1st	Copepods	Cope002	6.38			1.85	1.85	1.0019	20100731
				Cope003	6.17			1.55	1.77	1.0059	
				Cope004	6.46			1.67	1.82	1.0032	
				Cope005	6.62			1.75	2.02	1.0027	
				Cope006	6.42			1.23	1.77	1.0005	
				Cope17	6.3			1.72	1.97	1.0025	20100801
				Cope18	6.54			1.77	1.97	1.0061	
				Cope19	6.54			1.63	1.97	1.0025	
				Cope20	6.78			1.58	1.82	1.0037	
				Cope21	6.78			1.82	1.95	1.0083	
				Copr049	6.66			1.53	2.02	1.0044	20100808
				Cope050	6.02			1.33	1.82	1.0031	
				Cope051	6.46			1.48	2.02	1.0050	
20100801	14	MOHT_1st	Copepods	Cope007	6.62			1.63	2.02	1.0027	20100801
				Cope008	6.98			1.92	1.95	1.0016	
				Cope009	6.78			1.9	2.02	1.0027	
				Cope010	6.58			1.63	2.07	1.0027	
				Cope011	6.86			1.67	1.99	1.0016	
				Cope012	7.18			1.97	2.04	1.0026	
				Cope013	6.98			1.92	1.99	1.0015	
				Cope014	6.94			1.67	2.07	1.0009	
				Cope015	6.78			1.87	1.92	1.0025	
				Cope016	6.4			1.77	1.92	1.0025	
20100802	16	NORPAC	Copepods	Cope041	6.36			1.63	1.87	1.0064	20100808
				Cope042	6.7			1.72	2.02	1.0053	
				Cope043	6.46			1.63	2.12	1.0029	
				Cope044	6.82			1.58	2.27	1.0028	
				Cope045	3.92			1.08	1.28	0.9990	
				Cope046	3.94			1.08	1.33	0.9990	
				Cope047	3.72			1.03	1.28	1.0013	
				Cope048	3.89			1.03	1.43	1.0000	
20100802	17	NORPAC	Copepods	Cope028	6.7			1.77	2.02	1.0006	20100807
				Cope029	6.98			1.87	1.99	1.0032	
				Cope030	6.94			1.87	2.02	1.0025	20100808
				Cope031	6.9			1.72	2.07	1.0015	
				Cope032	6.7			1.67	1.9	1.0016	
				Cope033	6.7			1.77	1.97	1.0063	
				Cope034	6.74			1.72	1.92	1.0041	
				Cope035	6.7			1.82	2.02	1.0028	
				Cope036	3.72			0.94	1.18	1.0003	
				Cope037	3.79			0.98	1.31	1.0013	
				Cope038	3.77			1.03	1.28	0.9999	
				Cope039	3.89			1.18	1.26	1.0019	
				Cope040	3.64			1.03	1.13	1.0008	
20100803	18	NORPAC	Copepods	Cope055	3.82			0.98	1.23	1.0019	20100808
				Cope056	3.84			1.08	1.28	1.0008	
				Cope057	3.84			1.08	1.33	1.0036	
				Cope058	3.77			0.98	1.28	0.9995	

Table 9. Results of sighting survey for large cetacean species.

Species	Primary sighting		Secondly sighting	
	Schools	Animals	Schools	Animals
Sei whale	10	13	1	1
Fin whale	3	5		
Common minke whale	2	2	2	2
North Pacific right whale	2	2		
Humpback whale	2	2		
Sperm whale	2	2		
Total	21	26	3	3

Appendix 2

Oceanographic conditions in the survey area of offshore component of JARPN II in the western North Pacific in July to August 2010

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ABSTRACT

A whale sighting and whale prey species surveys were conducted from July 24 to August 4 in 2010 using R/V Hokko-Maru along with offshore component of JARPN II. The survey covered transition domain and subarctic area in the western North Pacific where sei whale was abundantly distributed in the baleen whale community. During the survey, oceanographic observation with CTD was operated to make clear the environment in and around the habitat of both cetaceans and its prey species. The survey area was almost located in the transition domain, except for two stations in the subarctic domain. The water mass was characterized by the subarctic water and the mixed water between the subarctic water and the Kuroshio water.

INTRODUCTION

Whale sighting and whale prey species surveys were conducted in the offshore area of the western North Pacific from July 24 to August 4 in 2010 using *R/V Hokko-Maru* (Fig. 1) in cooperation with the whale sampling survey by *Nisshin-Maru* and two sampling vessels. Sei whale *Balaenoptera borealis* was the most common baleen whales in the survey blocks.

There are a lot of water masses and fronts in the western North Pacific. The Oyashio flows southwestward along the Kuril Islands and turns eastward from the northern coast of Japan. The Kuroshio flows northward from the tropical area to Tohoku area east of Japan, and reaches near the Oyashio front. The Kuroshio turns eastward from the northern coast of Japan, and the strong eastward flow is called the Kuroshio Extension. Both major current, the Kuroshio Extension and the Oyashio, form Kuroshio-Oyashio Inter-frontal Zone. Water masses originated in the Kuroshio and the Oyashio are mixed each other in this zone and form new water masses.

In the high sea of the North Pacific Ocean, there are subarctic front (temperature front defined by 4℃) and the subarctic boundary (salinity front defined by 34.0psu) with a weak eastward flow. The subarctic front is south limit of the subarctic water and the subarctic boundary is north limit of the tropical water. The area between these fronts is called the transition domain (Favorite *et al*. 1976).

Each water mass in the western North Pacific has its own ecosystem, like a Kuroshio ecosystem, an Oyashio ecosystem, warm-core ring ecosystem, etc. So, we must make clear the oceanographic condition around whale's prey to build up a marine ecosystem model in this area. In this paper, distributions of water masses and fronts in the survey area will be described to make clear the environment of the distribution area of sei whale.

METHODS

Hydrographic observations with a conductivity-temperature-depth profiler (CTD) were carried out in the survey area from July 24 to 4 August in 2010 using *R/V Hokko-Maru* (Table 1 and Fig. 1). Salinity correction for CTD data was not done using water sampling data.

Locations of oceanic fronts and water masses are usually detected based on subsurface temperature map (see Table 2), because they are obscure in sea surface temperature distributions from summer to fall, and the Oyashio water spreads into the subsurface layer. The oceanographic conditions in July-August 2010 are detected by 100m and 200m temperature maps using our observation data by the vessel as well as NEAR-GOOS (the North-East Asian Regional-Global Ocean Observing System) database. We use following indices to know the distribution of water mass in the survey area. The Kuroshio Extension is defined by the 14℃ isotherm at the depth of 200m (Kawai , 1969). The warm water spread from Kuroshio Extension is defined by temperature more than 10℃ at the depth of 100 m. The subarctic front and the subarctic boundary is defined by 4℃ temperature front and 34.0 psu salinity front, respectively (Favorite *et al*. 1976).

RESULTS AND DISCUSSION

Oceanographic conditions in the survey area

Figure 2 shows the Temperature-Salinity diagrams in the survey area. There is no typical Kuroshio water characterized by high salinity profile around 34.5 psu. The warm water spread from the Kuroshio with warm (over 10℃) and high salinity (over 34 psu) water was observed at the surface layer in Stn. 1, only one station. The dominant water in this area was subarctic water characterized by cold profile less than 4℃, which is shown in lower part of Fig. 2. The mixed water in transitional domain is distributed between subarctic waters and warm water spread from the Kuroshio.

Figure 3 shows a schematic hydrographic map with isotherms of 100 m temperature from July 16 to August 15 in 2010. The cold water less than 5℃ at 100 m depth was distributed in a northern part of the survey area. The subarctic front, which is defined by 4℃ isotherm and corresponds to 33.4 psu isohaline in Fig. 5, was observed around 44° N, 158° E in Figs. 3 and 4. In 100 m salinity map (upper panel in Fig. 5), all of salinity value showed less than 34.0 psu, so the survey area was north of the subarctic boundary, which is defined by a salinity front of 34.0 psu. The warmest temperature at the 200 m depth was 6□, which was observed at southwestern part of this area (lower panel in Fig. 4). The Kuroshio Extension defined by 14℃ isotherm at 200 m depth meandered along 37° N line, far from our survey area.

Figure 6 shows temperature, salinity and density anomaly sections in the western part of the survey area. A seasonal thermocline lied at the depth of 50 m, and temperature at the surface mixing layer shallower than 30 m was warmer than 10℃ in this section. The subarctic water (colder than 4℃) was observed in deeper layer than 200 m in the southern part and 50 m in the northern part of this section. The subarctic front observed around 44° 15’N, where the 4℃ isotherm and 33.4 psu isohaline lie vertically. The salinity front around 34 psu (index of the subarctic boundary) is not appeared in this section, which indicates that this section was in the north of the subarctic boundary.

In the eastern part of the survey area (Fig. 7), a seasonal thermocline lied at the depth of 25 m that is shallower than western area. Temperature at the surface mixing layer shallower than 10-20 m was warmer than 10℃ in this section. The subarctic water (colder than 4℃) was observed in almost all of this section, deeper than 50 m depth. A little warm and high salinity water was observed at surface layer around 45° 30’N in Fig. 7, because the warmer water spread clockwise into this area (sea Fig. 3). 4℃ isotherm, which is index of the subarctic front, shows a shape of dome and 33.5psu isohaline looks like a bowl shape with a little cold low-salinity water around45° 30’N in this section. This cold low-salinity water was probably cut off from the subarctic domain and moved clockwise into this area. This water made a pair of warmer water around 45° 30’N, and clockwise eddy is revealed around 44° N, 164° E in Fig. 3. The salinity front around 34 psu was not appeared in this section same as the western section, which indicates that this survey area was located in the north of the subarctic boundary.

These figures show that the survey area was almost located in the transition domain, north of the subarctic boundary. Only two stations in the northwestern part of our survey area were in the subarctic domain, north of the subarctic front. The water mass was characterized by the subarctic water and the mixed water between the subarctic water and the Kuroshio water.

REFERENCES

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Kawai, H. 1969. Statistical estimation of isotherms indicative of the Kuroshio axis, *Deep-Sea Res*., Suppl. to 16: 109-115.

Table 1. Observation summary.

Ship	Instrument	Date	Number of stations
Hokko-Maru	CTD: BE 9plus	July 24 to August 4, 2010	20

Table 2. Extraction method from temperature map to determine the position of each water mass.

Target characteristics	Extraction method
Kuroshio Extension Axis	14°C isotherm at 200 m
Warm-core ring	Temperature front at 200 m
Oyashio front	5 °C isotherm at 100 m
Oyashio water	Area with T<5 °C at 100 m
Cold water	Area with 5°C<T<10 °C at 100 m
Warm water	Area with T>10 °C at 100 m and T<14 °C at 200 m
Subarctic Boundary	Salinity front defined by 34.0 psu
Subarctic Front	Temperature front defined by 4°C
Subarctic Domain	North of Subarctic Front
Transition Domain	Between Subarctic Front and Subarctic Boundary.

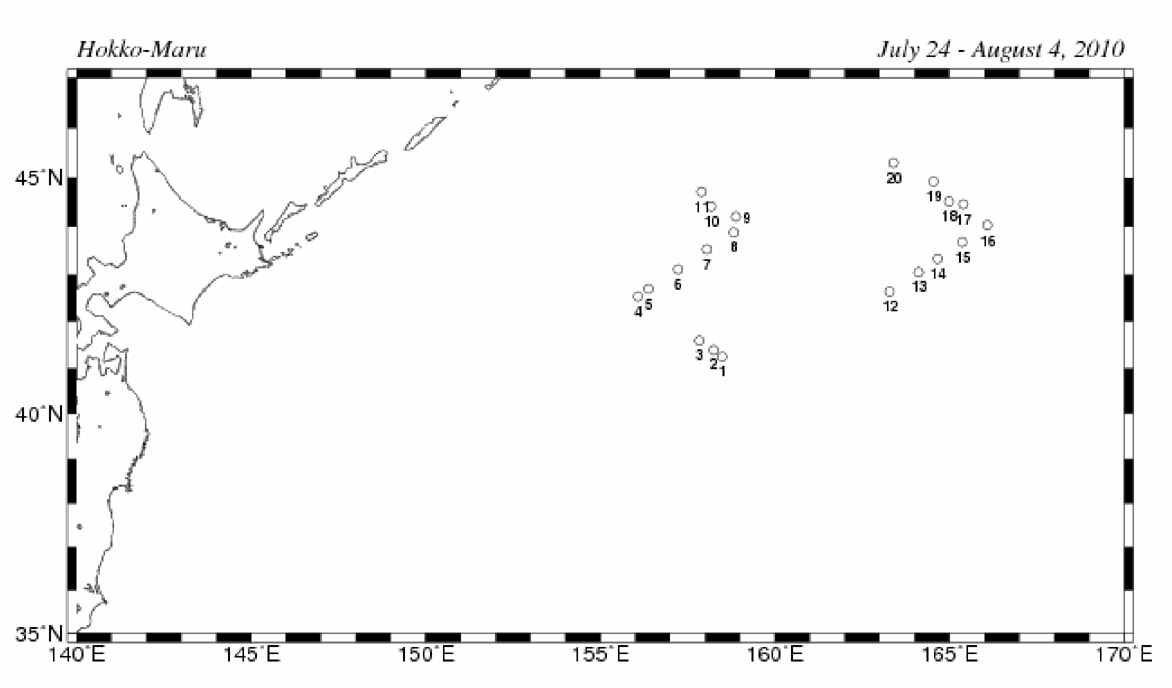

Fig. 1. Station map observed by *R/V Hokko-Maru in* 24th July to 4th August 2010.

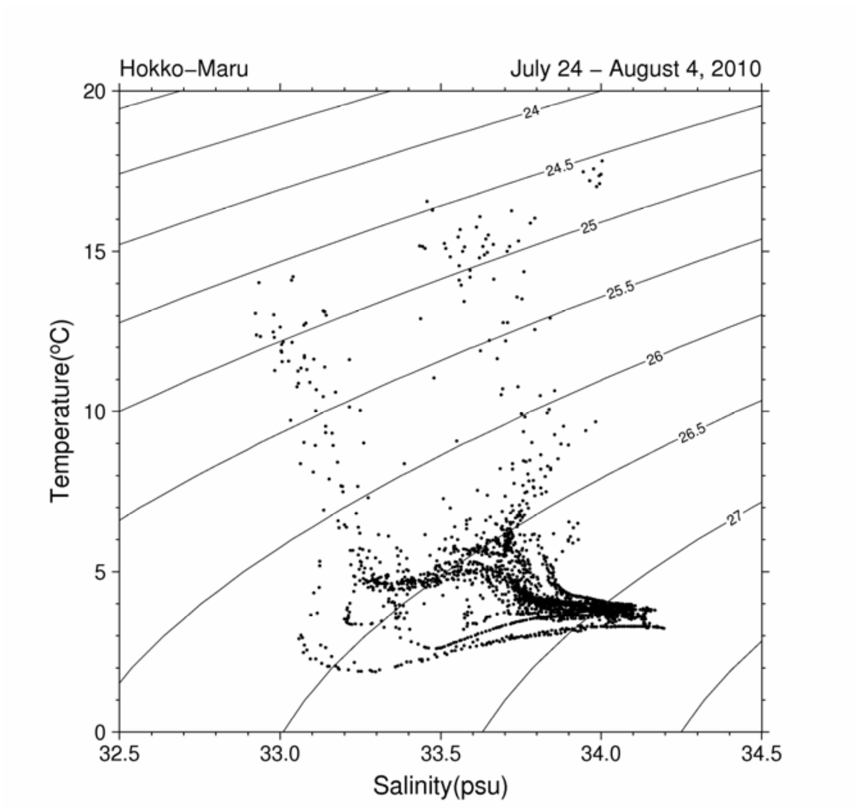

Fig. 2. Temperature-Salinity diagrams using CTD station data observed by *R/V Hokko-Maru.* Each thin line in this figure denotes a density line of sigma-t.

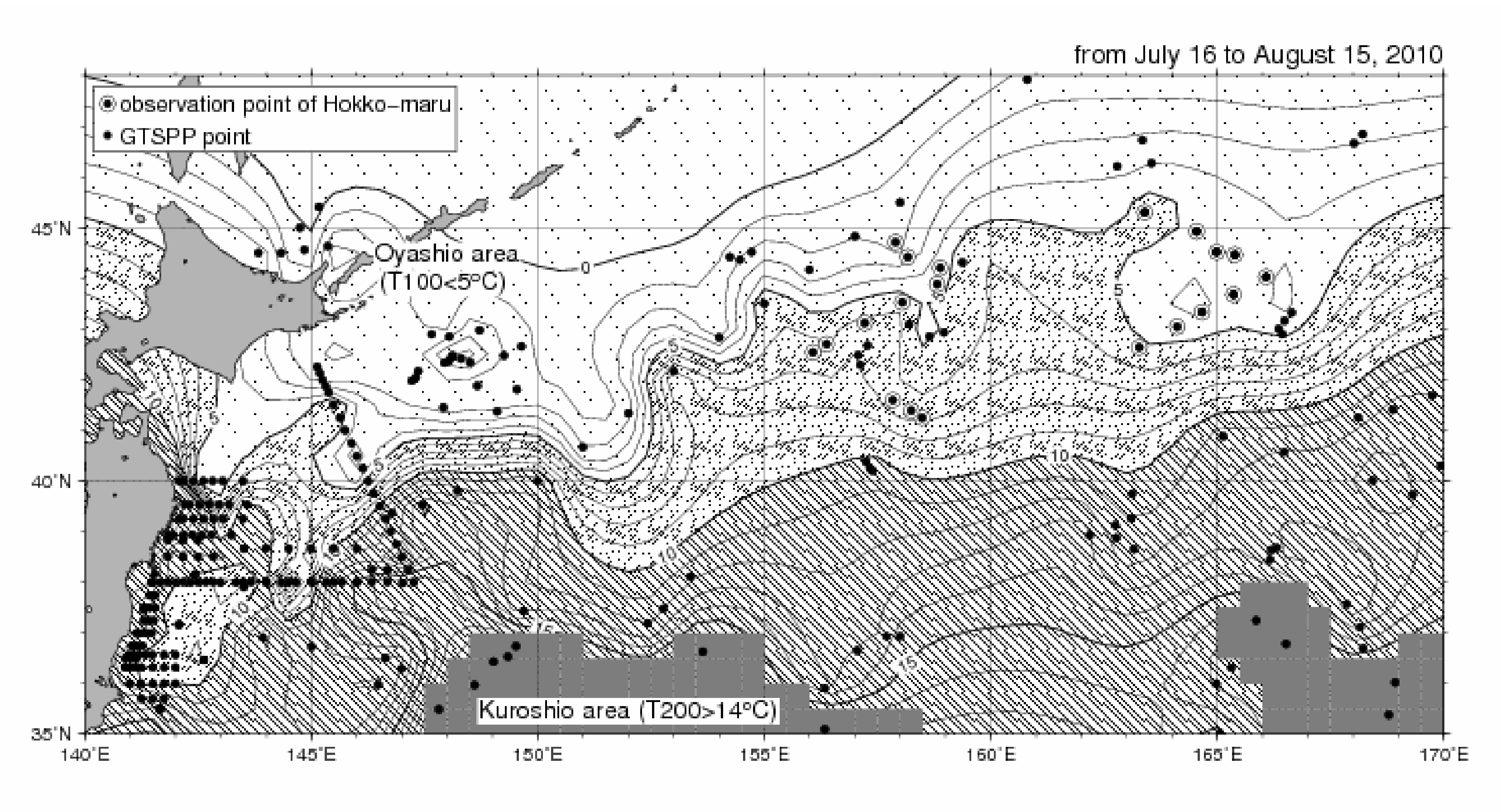

Fig. 3. Schematic hydrographic map in the western North Pacific between July 16 and August 15 in 2010 with station map observed by *R/V Hokko-Maru* and reported to GTSPP.

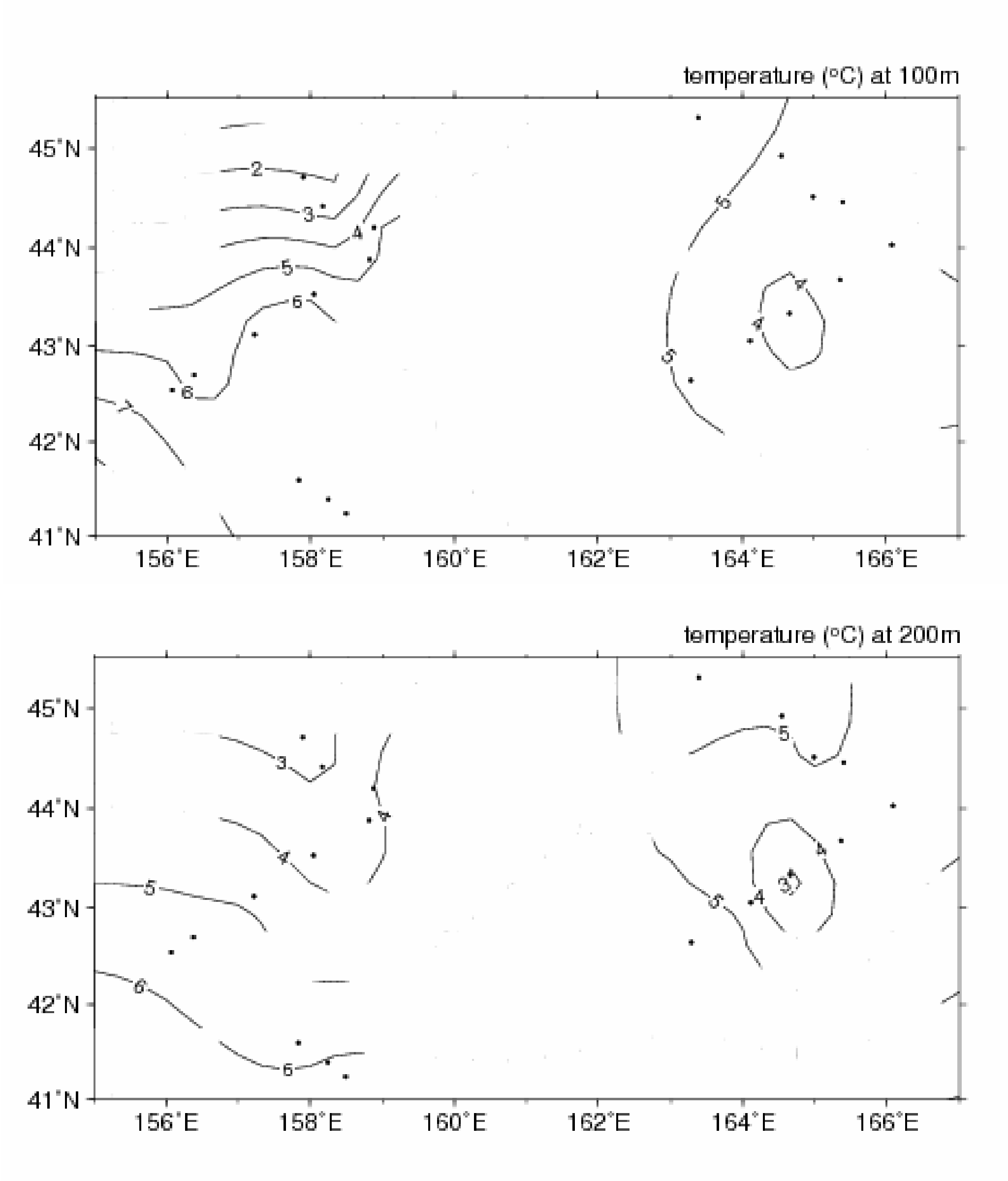

Fig. 4. Temperature at 100 m (upper panel) and 200 m depth (lower panel) observed by *R/V Hokko-Maru* from July 16 to August 15 in 2010.

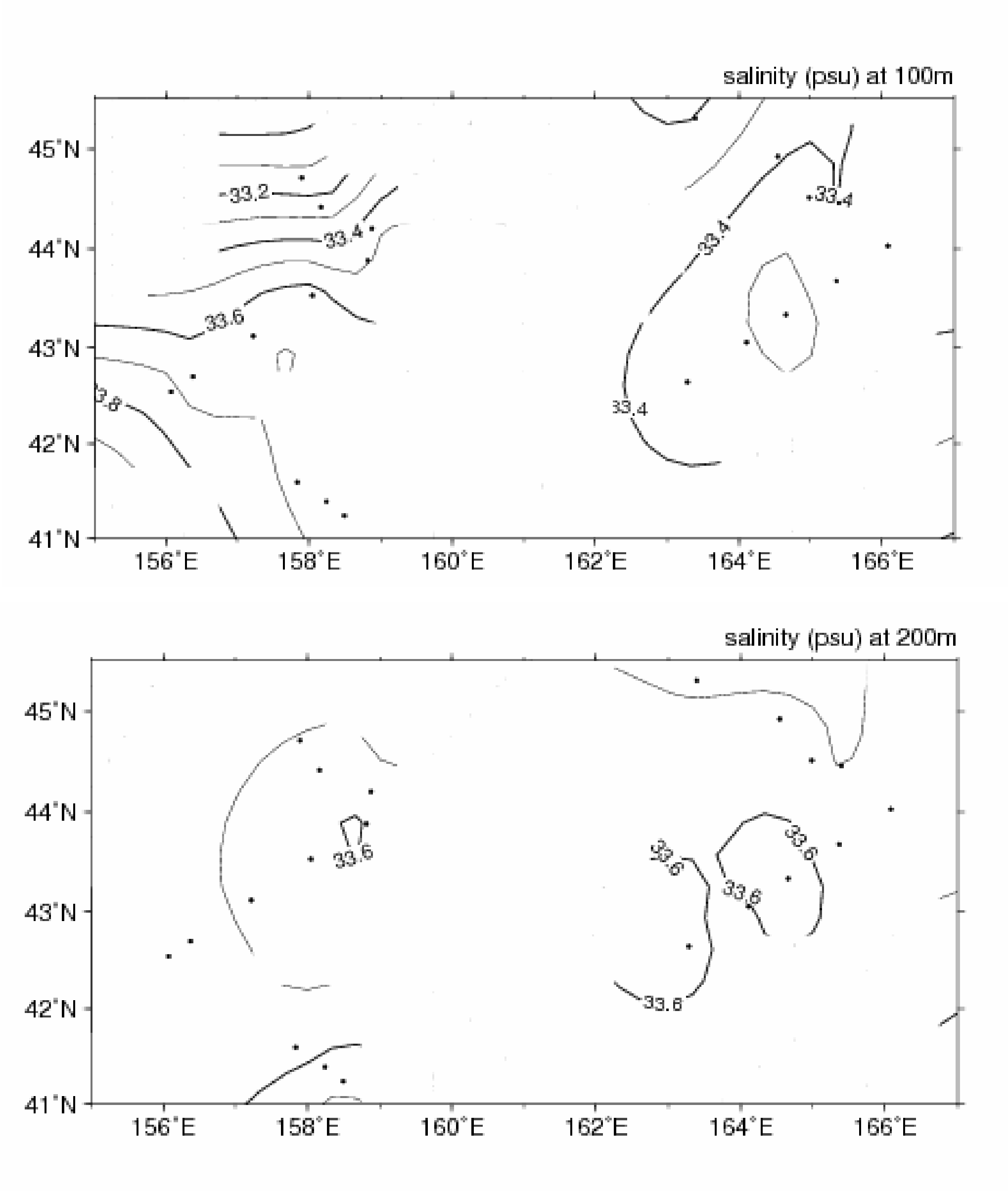

Fig. 5. Salinity at 100 m (upper panel) and 200 m depth (lower panel) observed by *R/V Hokko-Maru* from July 16 to August 15 in 2010.

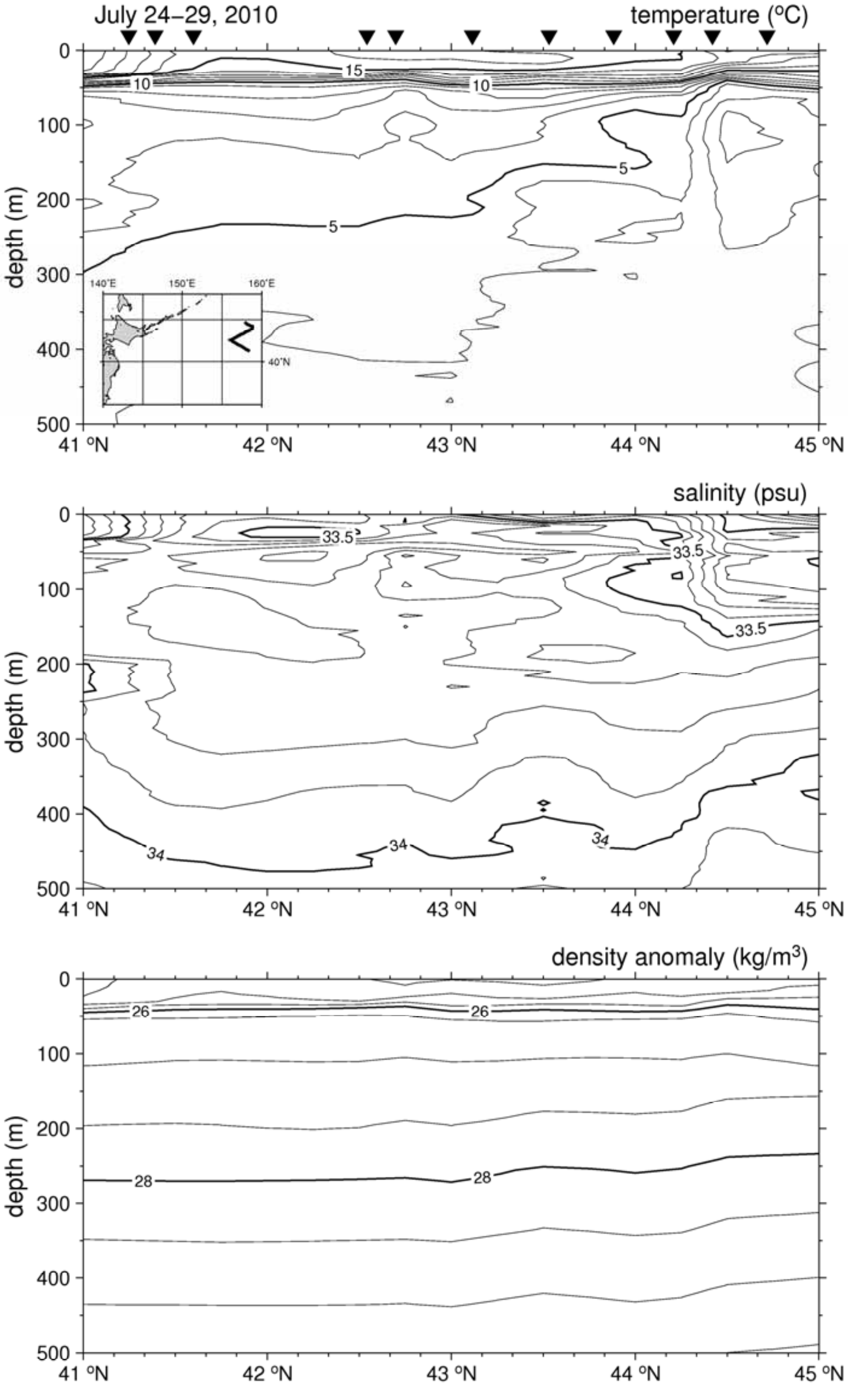

Fig. 6. Vertical sections from Stn.1 to Stn.11 of temperature (upper panel), salinity (middle panel) and density anomaly (lower panel) observed by *R/V Hokko-Maru* in July 24-29, 2010.

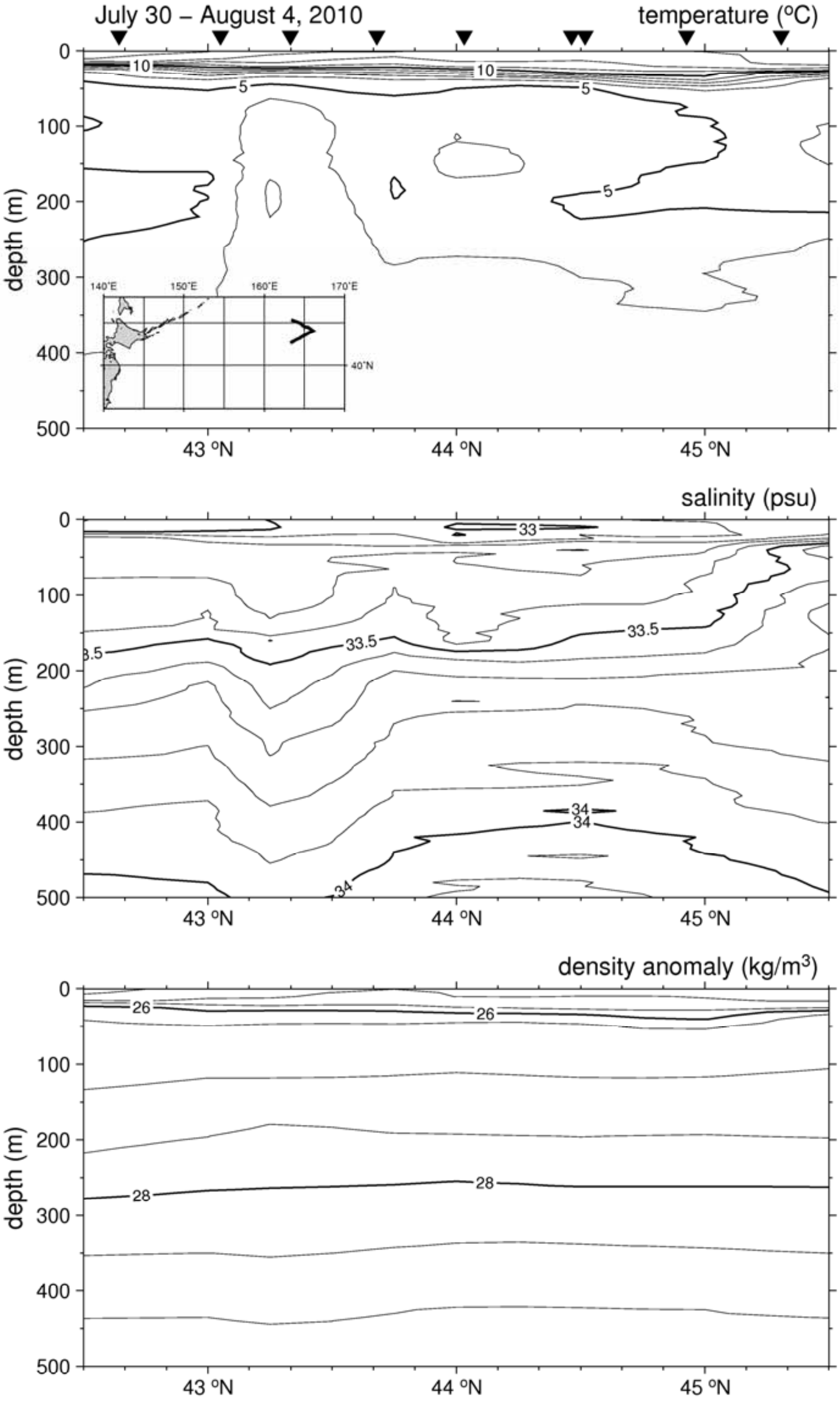

Fig. 7. Vertical sections from Stn.12 to Stn.20 of temperature (upper panel), salinity (middle panel) and density anomaly (lower panel) observed by *R/V Hokko-Maru* from July 30 to August 4, 2010.