Cruise Report of the Second Phase of the Japanese Whale Research Program under Special Permit in the Western North Pacific (JARPN II) in 2012 (part I) – Offshore component –

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ABSTRACT

The eleventh 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 in sub-areas 7, 8 and 9 of the western North Pacific. There were three main research components: whale sampling survey, dedicated sighting survey and whale sighting and prey survey. A total of five research vessels was used: two sighting/sampling vessels (SSVs) (whale sampling survey component), one research base vessel (*Nisshin Maru*, NM) (whale sampling survey component), one whale sighting and prey survey vessel (SPV) (whale sighting and prey survey component) and three dedicated sighting vessels (SVs) (dedicated sighting survey component). The whale sampling survey was carried out from 16 May to 3 August 2012. A total of 2,326n.miles was surveyed in a period of 69 days by the SSVs. A total of 86 common minke, 304 sei, 86 Bryde's, 218 sperm, five blue, 61 fin, 35 humpback and two right whales were sighted by the SSVs and *NM*. A total of 74 common minke, 100 sei, 34 Bryde's and three sperm whales was sampled by the SSVs. All whales sampled were examined on board of NM. In May and June, common minke whales fed mainly on Japanese anchovy near Shiriya-zaki, off northernmost region of Honshu, and walleye pollock off eastern Hokkaido, respectively. This indicates geographical differences of prey species in continental shelf region of sub-area 7. Sei whales fed mainly on Japanese anchovy, mackerels and copepods from June to July in sub-areas 8 and 9. Bryde's whales fed mainly on Japanese anchovy and krill in sub-areas 8 and 9 in July. Dominant prey species in the stomach of the sperm whales were various kinds of squids, which inhabit in mid- and deep-waters. The dedicated sighting surveys were carried out from 17 May to 30 June in sub-area 7, 20 August to 3 October in the area between 30°N to 40°N and 140°E to 170°E (this area contains sub-areas 7, 8 and 9), 14 September to 1 October in sub-area 7. A total of 2,728, 5,292 and 728n.miles was surveyed during each survey by the SVs, respectively. The whale sighting and prey surveys were carried out from 28 July to 15 August in 2012. Surveys were conducted with SSVs and *NM* in a part of sub-areas 8 and 9. The purpose of this survey in this year was to estimate habitat and prey preference of Bryde's whale and habitat preference of sei whale in relation to oceanographic and ecosystem information in those sub-areas in summer. Data obtained in this research will be used in the elucidation of the role of whales in the marine ecosystem through the study of whale feeding ecology in the western North Pacific.

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

INTRODUCTION

After the Japanese Whale Research Program under Special Permit in the Western North Pacific (JARPN) was completed in 1999, the second phase of Japanese Whale Research Program under Special Permit in the Western North Pacific (JARPNII) was started in the 2000 summer season as a two-year feasibility study. Based on the success of the feasibility study (Government of Japan, 2002a) and the increasingly strong support from international fisheries organizations, including FAO, for research to improve multi-species approaches to management, JARPN II started as a full-scale research program in 2002. The full-scale study aimed i) to evaluate the feeding ecology and ecosystem studies, ii) to monitor environmental pollutants in cetaceans and the marine ecosystem and iii) to elucidate the stock structure (Government of Japan, 2002b).

The full-scale JARPN II plan involves two survey components: the ‘offshore’ survey, which is covered by the *Nisshin Maru* research unit and two ‘coastal’ surveys (Sanriku and Kushiro), which are 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, 2002b).

The research area of the offshore component is set in sub-areas 7, 8 and 9, and the target species and sample sizes for the lethal component of the research were set as follows: 100 common minke whales; 100 sei whales, 50 Bryde’s whales and 10 sperm whales (Government of Japan, 2002b). The survey was composed of three main components: whale sampling survey, dedicated sighting survey and whale sighting and prey surveys.

In January 2009 IWC/SC conducted the Expert Workshop to review the ongoing JARPN II Programme (IWC, 2009) for the first period (2002-2007). The results presented on the three main objectives of JARPN II were discussed by an Experts Panel. Constructive discussions were conducted and some recommendations were offered by the EP. Some of those recommendations were already responded by Japanese scientists (Pastene, *et al*., 2010).

This paper reports the eleventh full-scale survey of the JARPN II -offshore component-, carried out in 2012.

MATERIALS AND METHODS

Whale sampling survey

Research area

Sub-areas 7, 8 and 9, excluding the EEZ zones of foreign countries, comprised the research area (Figure 1).

Research vessels

Three 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.

Methods for setting cruise track line and sighting procedure

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, 2012; Bando *et al.,* 2010; Matuoka *et al.*, 2007; Yasunaga *et al*., 2011). 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.

Sighting procedure for the whale sampling survey, dedicated sighting survey and whale sighting and prey surveys 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, 2012; Bando *et al.*, 2010; Matsuoka *et al.*, 2008; Yasunaga *et al*., 2011). 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 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 two n.miles or more and wind force of four or below). The *NSS mode* was used under bad weather conditions such as strong wind, heavy rain or fog but the collection of whale samples was still possible. 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 other 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 numbers and procedure of targeted whales
The target species and sample sizes in the 2012 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: 06:30-18:30 (12 hrs) in local time), 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 the research base vessel, where biological measurements and sampling were carried out.

Experiments
The following experiments and observations were conducted by the SSVs:

1. Sighting distance and angle experiments to examine the precision of sighting data.
2. Biopsy sampling on gray, blue, fin, sei, Bryde's, common minke, humpback, right, bowhead and sperm whales.
3. Photographic records of natural marks on blue, humpback and right whales.
4. Observation of feeding behaviour on blue, fin, sei, Bryde's, common minke, humpback, right and sperm whales.
5. Observation of excretion and vomiting behaviour on sei, Bryde's, common minke and sperm whales.

Observation of marine debris

Observation of marine debris was conducted from the wheelhouse of the research base vessel (*NM*) during transit from home port to the research area (16 May to 20 May) and from research area to home port (29 July to 3 August). Marine debris was also investigated in the stomach contents of common minke, Bryde's, sei and sperm whales sampled.

Dedicated Sighting survey
A report of the dedicated sighting surveys was presented by Matsuoka *et al*. (2013). Here just a brief outline is presented. Three independent surveys were conducted in this season.

Research area
First survey: sub-area 7
Second survey: between 30°N to 40°N, 140°E to 170°E
Third survey: sub-area 7

Research vessel
The *YS1*, *YS2* and *Yushin Maru* No.3 (*YS3*: 742GT) were used as dedicated sighting vessel (SV).

Methods for setting cruise track line and sighting procedure
An independent track line for dedicated sighting survey was designed in the research area.

Experiments
The following experiments and observations were conducted by the SVs.

1. Sighting distance and angle experiments to examine the precision of sighting data.
2. Biopsy sampling on gray, blue, fin, sei, Bryde's, common minke, humpback, right, bowhead and sperm whales.
3. Photographic records of natural marks on blue, humpback and right whales.
4. Observation of feeding behaviour on blue, fin, sei, Bryde's, common minke, humpback, right and sperm whales.
5. Satellite tag tracking on large whales.

Whale sighting and prey surveys
A report of this survey is presented in the Appendix. The objective of the survey in this year was to examine habitat and prey preference of Bryde's whale and habitat preference of sei whale in late summer.

Research area
Research area was set in sub-areas 8 and 9.

Research vessel
The *Shunyo Maru* (*SYO*: 887GT) was used as whale sighting and prey survey vessel (SPV).

Methods for setting cruise track line and survey procedure
Survey for Bryde's whale was conducted simultaneously at the same track line of whale sampling survey within 6 days. Survey for sei whale was conducted independently.

Experiments

The following experiments and observations were conducted by the SPV.

1. Sighting of cetaceans from top barrel.
2. Record of oceanographic conditions by CTD.
3. Collection of data for the estimation of abundance of prey species: chlorophyll, echo sounder, mid-water trawl, BONGO net and twin NORPAC net surveys.

RESULTS

Whale sampling survey
Actual survey periods, track lines and searching distances

Cruise period: Between 16 May and 3 August (80 days)

Research period: Between 21 May and 28 July (69 days)

Track line: Track line set by the two SSVs is shown in Figure 2.

Searching distance: The total searching distance for SSVs was 2,326 n.miles

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

A total of 82 schools (86 individuals) of common minke whales was sighted, consisting of 14 schools (15 ind.) of primary and 68 schools (71 ind.) of secondary sightings. For sei whale, 170 schools (304 ind.) were sighted, consisting of 52 schools (83 ind.) of primary and 118 schools (221 ind.) of secondary sightings. For Bryde's whale, 70 schools (86 ind.) were sighted, consisting of 34 schools (45 ind.) of primary and 36 schools (41 ind.) of secondary sightings. For sperm whale, 84 schools (218 ind.) were observed, consisting of 45 schools (111 ind.) of primary and 39 schools (107 ind.) of secondary sightings (Table 1).

Sightings of other large cetacean species

Table 1 also shows the number of sightings for other large whale species made by the SSVs, including large baleen whales such as blue (five schs./five inds.), fin (45 schs./61 inds.), humpback (29 schs./35 inds.) and right whales (two schs./two inds.).

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

A total of 74 common minke whales (male: 58 individuals, female: 16 individuals), 100 sei whales (male: 44, female: 56 ind.), 34 Bryde's whales (male: 11, female: 23 ind.) and three sperm whales (male: 1, female: 2 ind.) were sampled. Struck and lost did not occur in this survey. Table 2 summarizes the biological data and samples collected from whales. A total of 46 research items was covered. 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, Bryde's and sperm whales are shown in Table 3. Statistics of body length of each whale species is shown in Table 4. Mean body length of common minke whales was 6.88m and 6.26m for males and females, respectively. For sei whales, those were 13.26m and 14.26m, respectively. For Bryde's whales, those were 11.61m and 12.52m, respectively. For sperm whales, body length was 8.71m for one male and 9.84 and 11.51m for two females, respectively.

Geographical distribution of common minke, sei, Bryde's and sperm whale samples is shown in Figure 3 based on the sighting positions.

Distribution and food habits of whales

During the research period, common minke whales fed mainly on Japanese anchovy (*Engraulis japonicus*) (49.2%) and walleye Pollock (*Theragra chalcogramma*) (36.1%) (Table 5). Almost all common minke whales were sampled in or around continental shelf region in the northern part of sub-area 7 in May and June. Common minke whales fed mainly on Japanese anchovy near Shiriya-zaki, off northernmost region of Honshu and walleye pollock off eastern Hokkaido.

Sei whales were distributed widely in the offshore area. In this survey, almost all sei whales were sampled in the sub-areas 8 and 9 and they fed mainly on copepods (55.7%), Japanese anchovy (16.5%) and mackerels (12.7%) (Table 5).

Bryde's whales were distributed in the southern part of the research area. In this survey, almost all Bryde's whales were sampled in the sub-areas 8 and 9 and they fed mainly on Japanese anchovy (65.0%), followed by krill (30.0%) in July (Table 5).

Sperm whales were also distributed widely in the research area. In this survey, three sperm whales were sampled in the sub-area 7. Main prey species were deep sea squids.

Experiments

Sighting distance and angle experiment

A sighting distance and angle experiment was performed on 28 June 2012 by *YS1* and *YS2*. The results of this experiment will be used in calculation of abundance estimates.

Photo-ID and biopsy sampling
Two right whales were photographed by the SSVs. A total of five biopsy samples were collected from one right and four sei whales by the SSVs.

Feeding behaviour
No case of feeding was observed in the research.

Excretion and vomiting behaviour
No case of excretion or vomiting was observed in the research.

Observation of marine debris

No large debris was observed in the environment.

Small piece of plastic was observed in the stomachs of five common minke, 44 sei and ten Bryde's whales. Small piece of wood was observed in three minke, four sei and one Bryde's whales. One to five pieces were observed in each individual and sizes were less than 15cm in most cases.

Dedicated Sighting survey (see details in Matsuoka *et al*., 2013)
Actual research periods and searching distance

Cruise period:

First survey : Between 17 May and 30 June (45 days; *YS3*)

Second survey : Between 20 August and 3 October (45 days; *YS1*, *YS2*)

Third survey : Between 14 September and 1 October (18 days; *YS3*)

Searching distance:

First survey : 2,728.3 n.miles (*YS3*)

Second survey : 2,482.9 n.miles (*YS1*); 2,808.9 n.miles (*YS2*)

Third survey : 727.6 n.miles (*YS3*)

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

A total of 42 schools (51 individuals) of common minke, 35 schools (49 ind.) of Bryde's, 11 schools (14 ind.) of sei and 71 schools (168 ind.) of sperm whales was sighted during first survey. During second survey, a total of 102 schools (134 ind.) of Bryde's and 93 schools (251 ind.) of sperm whales was sighted. A total of 20 schools (24 ind.) of common minke, one school (one ind.) of sei and five schools (seven ind.) of sperm whales was sighted during third survey.

Sightings of other large cetacean species

Large baleen whales such as fin (four schools/10 individuals) and humpback (32 sch./42 ind.) were sighted during first survey. During second survey, blue (one sch./one ind.) and fin (one sch./one ind.) whales were sighted. Fin whale (five sch./six ind.) was sighted during third survey.

Experiments

Photo-ID and biopsy sampling

Ten humpback whales were photographed during first survey and one blue whale was photographed during the second survey. A total of 44 biopsy samples were collected from one blue, one fin and 42 Bryde's whales during second survey.

Feeding behaviour

No case of feeding was observed in the research.

Satellite tag tracking

During the first survey, YS3 attempted the attachment of a satellite tag on humpback whale (one school/two animals), sei whale (one school/one animal) and common minke whales (two schools/four animals), but not succeeded.

Whale sighting and prey surveys (see details in Appendix)

Actual research period and searching distance

Cruise period: Between 25 July and 21 August (28 days)

Research period: Between 28 July and 15 August (19 days)

Searching distance: 812 n.miles.

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

A total of 58 schools (72 individuals) of Bryde's, 15 schools (19 ind.) of sei and 27 schools (96 ind.) of sperm whales was sighted as primary sighting.

Sightings of other large cetacean species

No other large whale species were observed.

Main experiments

CTD: 33 points

Midwater trawl: 11 points

Twin NORPAC net survey: 29 points

BONGO net survey: 16 points

Fluorescence survey: 16 points

Water sampling survey: 16 points at 0, 10, 30, 50, and 100 m depths

DISCUSSION

Prey species and food habits of common minke, sei, Bryde's and sperm whales in the 2012 survey is discussed below in the context of previous survey results.

Common minke whale

From the JARPN and JARPN II surveys from 1994 to 2011, common minke whales fed on various prey species such as Japanese anchovy, Pacific saury *Cololabis saira*, walleye pollock and Japanese common squid *Todarodes pacificus*, and the main prey species changed seasonally and geographically. For example, they fed on Japanese anchovy in May/June and Pacific saury in July/August in offshore area (Tamura *et al*., 2009c).

In the 2012 survey, it was confirmed that walleye pollock is an important prey species for minke whales off eastern Hokkaido during early feeding season (May to June), which was also confirmed by the previous coastal survey (Yasunaga *et al*, 2012). During the same season, Japanese anchovy was the main prey species off Shiriya-zaki. It is reasonable to assume that common minke whales do not have a strong preference for a particular prey species. Changes in the prey species reflect changes in the abundance or availability of prey species in the area.

Sei whale

From our research results of past JARPN II (2002 to 2011), they fed on Japanese anchovy and copepods dominantly during survey season in most of years (Tamura *et al*., 2009c).

During the present survey, sei whales fed mainly copepods, Japanese anchovy and mackerels in offshore zone of research area. In recent surveys, mackerels were occasionally observed as prey species, which might indicate recovery of this resource.

Bryde's whale

From our research results of past JARPN II (2000 to 2011), the dominant prey species of Bryde's whale was Japanese anchovy and krill during May to September. There was seasonal change of prey species. In early season (May and June) the dominant prey species was krill. In late season (from July to September), the dominant prey species was Japanese anchovy in sub-areas 7 and 8. In the south eastern part of sub-area 9, oceanic lightfish were also important prey species in August.

During the present survey, Bryde's whale fed mainly on Japanese anchovy followed by krill in July in the sub-areas 8 and 9. These results were the same as in previous surveys.

Sperm whale

From our research results of past JARPN II (2000 to 2011), the following information was obtained: (1) sperm whales feed mainly on deep-sea squids. Some of these are reported as prey species of the sperm whale for the first time; (2) Squids found in the sperm whale stomach are relatively fresh suggesting that sperm whale feed on these prey during daytime; (3) At least some fish species (walleye pollock, bottom fishes) was identified in the diet of the sperm whale (Tamura *et al*., 2009d). During the present survey the food habit of sperm whale was the same as in previous surveys.

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Table 1. Whale species and number of sightings in the 2012 JARPN II survey (no. schools/no. individuals)

Sighting/sampling vessels (YS1 and YS2)

Species	Primary		Secondary		Total	
	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Common minke whale	14	15	68	71	82	86
Like minke whale	0	0	7	7	7	7
Sei whale	52	83	118	221	170	304
Bryde's whale	34	45	36	41	70	86
Sperm whale	45	111	39	107	84	218
Blue whale	1	1	4	4	5	5
Fin whale	13	17	32	44	45	61
Humpback whale	14	16	15	19	29	35
Right whale	0	0	2	2	2	2

Table 2. Summary of biological data and samples collected during the 2012 JARPN II survey.

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	16	58	74	56	44	100	23	11	34	2	1	3
External body proportion	16	58	74	56	44	100	23	11	34	2	1	3
Photographic record and external character	16	58	74	56	44	100	23	11	34	2	1	3
Diatom film record	16	58	74	56	44	100	23	11	34	2	1	3
Standard measurements of blubber thickness (five points)	16	58	74	56	44	100	23	11	34	2	1	3
Detailed measurements of blubber thickness (eleven points)	0	1	1	1	0	1	1	0	1	0	1	1
Body weight	16	58	74	56	44	100	23	11	34	2	1	3
Body weight by parts	0	1	1	1	0	1	1	0	1	0	1	1
Blubber tissues for DNA study	16	58	74	56	44	100	23	11	34	2	1	3
Kidney tissues for heavy metal analysis	0	0	0	40	24	64	0	0	0	0	0	0
Blubber, muscle, liver and kidney tissues for organochlorines analysis	16	58	74	56	44	100	23	11	34	2	1	3
Tissue for nutritional compornent analysis	1	4	5	2	3	5	3	2	5	0	0	0
Lung tissue for atmospheric analysis	0	10	10	0	10	10	0	6	6	2	1	3
Muscle tissues for cesium analysis	4	7	11	6	4	10	5	5	10	2	1	3
Tissues for various analysis	16	58	74	56	44	100	23	11	34	2	1	3
Tissues for virus test	-	58	58	-	44	44	-	11	11	-	1	1
Mammary gland; lactation status and measurement	16	-	16	56	-	56	23	-	23	1	-	1
Collection of ovary	16	-	16	56	-	56	23	-	23	2	-	2
Photographic record of foetus	3	1	4	18	20	38	4	6	10	0	1	1
Foetal sex (identified by visual observation)	3	1	4	18	20	38	4	6	10	0	1	1
Foetal length and weight	3	1	4	18	20	38	4	6	10	0	1	1
Foetal blubber tissues for DNA study	3	1	4	18	20	38	4	6	10	0	1	1
Testis; weight and histological sample	-	58	58	-	44	44	-	11	11	-	1	1
Collection of plasma sample	16	58	74	56	44	100	23	11	34	2	1	3
Stomach content, conventional record	14	58	72	56	44	100	23	11	34	2	1	3
Weight of stomach content in each compartment	14	58	72	56	44	100	23	11	34	2	1	3
Stomach contents for feeding study	14	58	72	56	44	100	23	11	34	2	1	3
Record of external parasites	16	58	74	56	44	100	23	11	34	2	1	3
Collection of external parasites	0	0	0	1	1	2	2	1	3	0	0	0
Record of internal parasites	16	58	74	56	44	100	23	11	34	2	1	3
Collection of internal parasites	0	0	0	1	0	1	0	0	0	2	0	2
Earplug for age determination	16	58	74	56	44	100	23	11	34	0	0	0
Tympanic bulla for age determination	0	1	1	1	0	1	1	0	1	0	0	0
Maxillally teeth for age determination	0	0	0	0	0	0	0	0	0	2	1	3
Lens for age determination	16	58	74	56	44	100	23	11	34	2	1	3
Largest baleen plate for morphologic study and age determination	16	58	74	56	44	100	23	11	34	-	-	-
Vertebral epiphyses sample	16	58	74	56	44	100	23	11	34	2	1	3
Brain weight	0	1	1	1	0	1	1	0	1	0	1	1
Skull measurements (length and breadth)	16	58	74	56	43	99	23	11	34	2	1	3
Pelvic bone	16	58	74	56	44	100	23	11	34	2	1	3
Foetal pelvic bone	3	1	4	18	20	38	4	6	10	0	1	1
Detailed measurements of pectoral fin for morphological study	16	58	74	0	0	0	0	0	0	0	0	0
Photographic record of pectoral and caudal fin for morphological study	16	58	74	0	0	0	0	0	0	0	0	0
Collecton of fetus for histological study	0	0	0	1	1	2	0	0	0	0	0	0
Testis tissues for morphological study	-	0	0	-	10	10	-	4	4	-	0	0
Placenta tissues for morphological study	0	-	0	9	-	9	6	-	6	0	-	0

Table 3. Sex and sexual maturity composition of whales sampled during the 2012 JARPN II survey.

Species	Sub area	Male				Female								Total
							Mat.							
		Imm.	Mat.	Uk	Total	Imm.	Ovu.	Rest.	Preg.	Lact.	Preg. Lact.	Total	Total	
Common minke	SA7	21	29	5	55	12	0	0	4	0	0	4	16	71
	SA8	0	1	2	3	0	0	0	0	0	0	0	0	3
	SA9	0	0	0	0	0	0	0	0	0	0	0	0	0
	Combined	21	30	7	58	12	0	0	4	0	0	4	16	74
Sei	SA7	0	0	0	0	0	0	0	0	0	0	0	0	0
	SA8	3	12	0	15	4	0	3	14	0	0	17	21	36
	SA9	10	19	0	29	7	2	2	22	1	1	28	35	64
	Combined	13	31	0	44	11	2	5	36	1	1	45	56	100
Bryde's	SA7	0	0	0	0	0	0	0	0	0	0	0	0	0
	SA8	3	2	0	5	3	0	4	4	0	0	8	11	16
	SA9	2	4	0	6	1	0	4	6	1	0	11	12	18
	Combined	5	6	0	11	4	0	8	10	1	0	19	23	34
Sperm	SA7	0	0	1	1	0	0	0	1	1	0	2	2	3
	SA8	0	0	0	0	0	0	0	0	0	0	0	0	0
	SA9	0	0	0	0	0	0	0	0	0	0	0	0	0
	Combined	0	0	1	1	0	0	0	1	1	0	2	2	3

Table 4. Body length (m) of whales sampled during the 2012 JARPN II survey.

Species	Sub area	Male					Female				
		n	mean	S.D.	min	max	n	mean	S.D.	min	max
Common minke	SA7	55	6.84	0.77	5.01	8.16	16	6.26	1.24	4.73	8.48
	SA8	3	7.54	0.40	7.10	7.87	0				
	SA9	0					0				
	Combined	58	6.88	0.77	5.01	8.16	16	6.26	1.24	4.73	8.48
Sei	SA7	0					0				
	SA8	15	13.51	0.65	12.56	15.14	21	14.41	0.84	12.76	15.98
	SA9	29	13.13	1.16	9.80	14.51	35	14.17	1.23	9.91	15.72
	Combined	44	13.26	1.03	9.80	15.14	56	14.26	1.10	9.91	15.98
Bryde's	SA7	0					0				
	SA8	5	11.37	1.87	9.35	13.38	11	12.20	1.43	8.96	13.99
	SA9	6	11.81	1.45	9.08	13.06	12	12.82	0.62	11.68	13.78
	Combined	11	11.61	1.58	9.08	13.38	23	12.52	1.10	8.96	13.99
Sperm	SA7	1	8.71				2	10.68	1.18	9.84	11.51
	SA8	0					0				
	SA9	0					0				
	Combined	1	8.71				2	10.68	1.18	9.84	11.51

Table 5. Prey species and stomach contents weight (1st. + 2nd. stomachs) in whales sampled during the 2012 JARPN II survey.

Dominant prey species			N	%	Range of weight (kg)		
Common minke whale							
	Krill		7	11.5	12.08	-	68.96
	Copepods	Neocalanus spp.	1	1.6	16.54		
	Fish	Japanese anchovy	30	49.2	1.84	-	209.45
		Japanese sardine	1	1.6	62.42		
		Walleye pollock	22	36.1	8.02	-	119.60
Sei whale							
	Krill		7	8.9	9.34	-	618.29
	Copepods	Neocalanus spp.	44	55.7	11.06	-	294.84
	Fish	Japanese anchovy	13	16.5	35.44	-	708.75
		Squids	1	1.3	128.20		
		Mackerels	10	12.7	26.38	-	399.55
		Pacific saury	3	3.8	19.00	-	77.94
		Unidentified	1	1.3	24.60	-	24.60
Bryde's whale							
	Krill		6	30.0	45.14	-	175.78
		Japanese sardine	1	5.0	324.64		
	Fish	Japanese anchovy	13	65.0	34.44	-	521.86

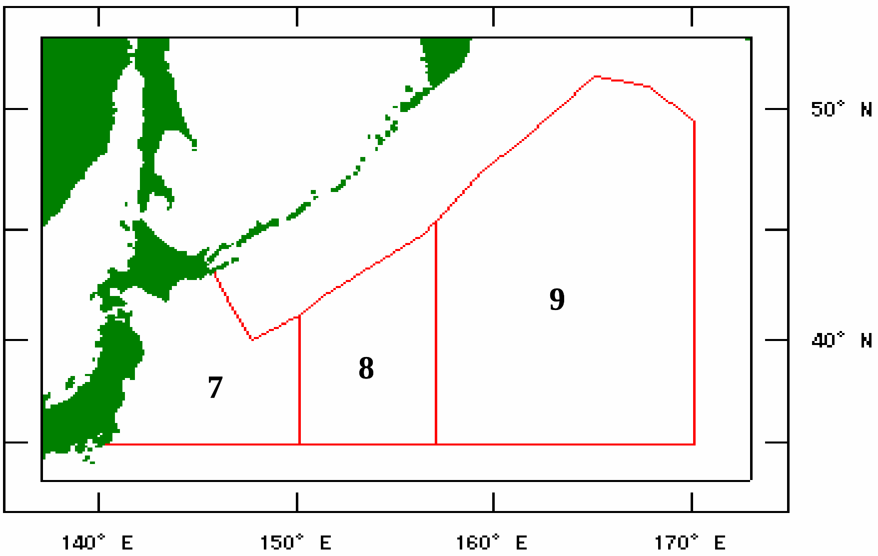

Figure 1. Research area of the JARPN II full-scale program.

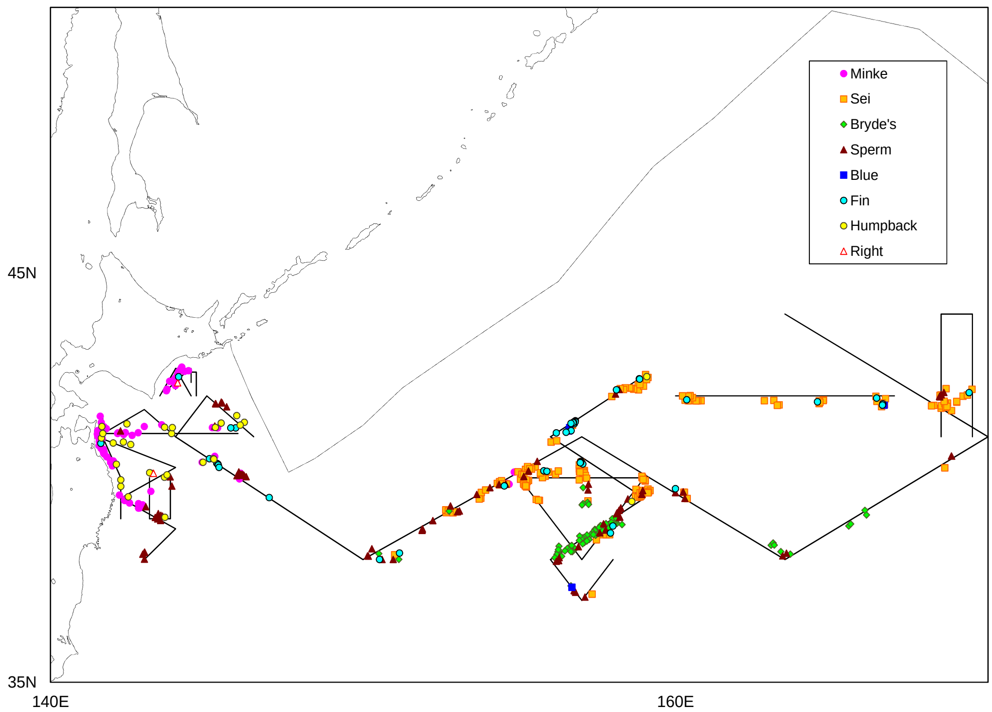

Figure 2. Track-lines and sighting positions of large whales made by the sighting/sampling vessels (SSVs).

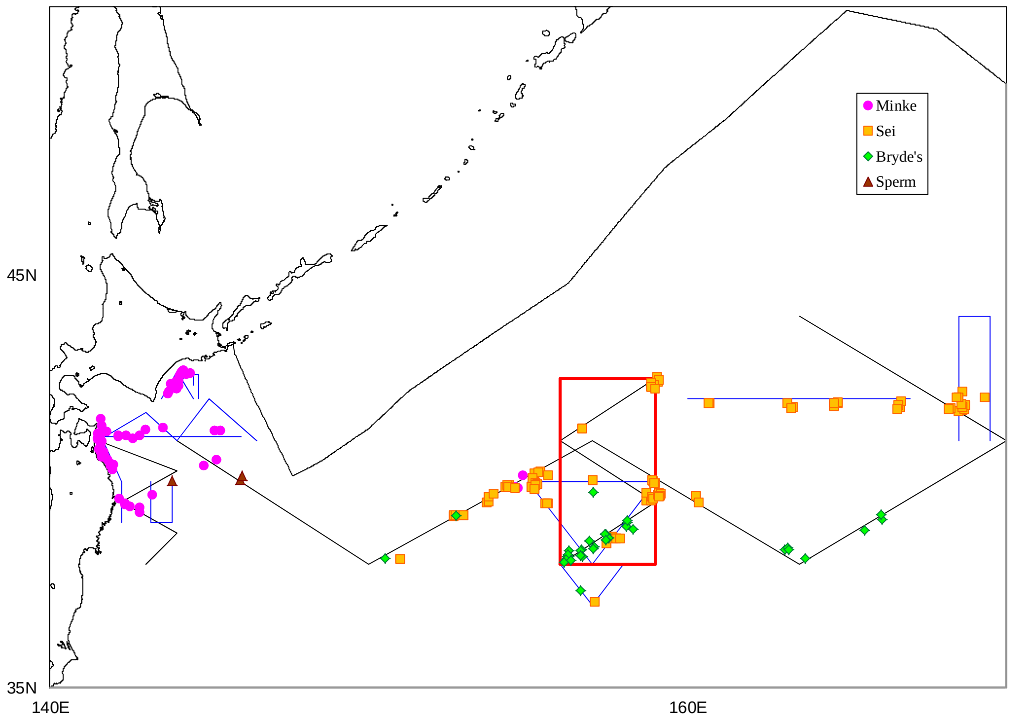

Figure 3. Sighting positions of the sampled common minke (pink circle), sei (orange square), Bryde's (green diamond) and sperm (brown triangle) whales. Red block shows the survey area for the cooperative prey and whale sampling survey. Blue lines were special monitoring surveys

APPENDIX
Cruise report of JARPN II whale sighting and prey surveys in conjunction with whale sampling survey in the offshore region of the western North Pacific in 2012

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ABSTRACT

Whale sighting and prey surveys were carried out in the transition region of the western North Pacific in the boundary zone of sub-area 8 and 9 in late July and early August 2012. The objective of these surveys in this year was to examine habitat selection of sei whale *Balaenoptera borealis* and habitat and prey selections of the Bryde's whale *B. edeni* in this area in late summer in relation to oceanographic and ecosystem information. Survey on Bryde's whale was conducted with whale sampling survey at the same area within 6 days. Sei whale was mainly found in the northern area north of 41ºN where was the main habitat of adult Japanese anchovy *Engraulis japonica* and adult Japanese common mackerel *Scomber japonicus*, both of which were frequently fed on by the whale according to the past data of JARPN II. In June 2011, we conducted whale sighting and prey surveys at the same area and sei whale was mainly found more southern area south of 39˚N, where was also the main habitat of adult Japanese anchovy and Japanese common mackerel. These facts suggest that sei whale migrate to the northward following northward migration of these preys from early to late summer. Bryde's whale was mainly found in the area south of 39º30'N where was the main habitat of juvenile Japanese anchovy and Japanese sardine *Saldinops melanostictus*, indicating that this species selected main distribution area of these fish preys as their main feeding ground. Bryde's whale was not found in our survey in June 2011, suggesting that this species migrate into the study area during mid and late summer. Distribution of these whale species in relation to primary production was also depicted.

KEY WORDS: SEI WHALE, BRYDE’S WHALE, HABITAT SELECTION, WHALE SIGHTING AND ECOSYSTEM SURVEYS, OFFSHORE REGION, WESTERN NORTH PACIFIC, LATE SUMMER.

INTRODUCTION

To obtain various parameter for ecosystem modeling like prey preference of the whale, The Second Phase of the Japanese Whale Research Program under Special Permit in the Western North Pacific (JARPN II) have conducted ‘‘whale prey species survey’’ in conjunction with whale sampling survey to estimate abundance of whale prey species in the environment in the offshore region of the western North Pacific (Government of Japan 2002). At the IWC/JARPN II review workshop in 2009, the Expert Panel recommended estimation of functional relationship of each whale species (relationship between distribution density of each prey species in environment and dietary intake of each individual of the whale for each prey species), which is a wide-use parameter for various ecosystem models as well as prey preference (IWC 2010). The Expert Panel also recommended accumulating quantitative ecosystem information in the subtropical, transition, and subarctic regions, respectively, to construct ecosystem models in each region (IWC 2010), although JARPN II modeling group built several ecosystem models to cover the whole part of sub-area 7, 8, and 9 (Kawahara 2009, Mori et al. 2009). Based on these comments, we newly started ‘‘whale sighting and prey surveys’’ from 2010 or 2011 by the following approach.

1. Whale prey species survey vessel conducts whale sighting survey.
2. These surveys and whale sampling survey conduct on the same track line at the same period to obtain the data on prey abundance in environment and stomach contents of the whale simultaneously.
3. Whale sighting and prey species survey vessel conducts various observations of physical and biological conditions to obtain major ecosystem information including whales in various region and month.

These surveys are firstly adopted in the western North Pacific and the major parameters of ecosystem models could be obtained directly and quantitatively from the field data. Furthermore, whale sighting and prey surveys are also essential for single species management of whales, since both extra- and interpolation methods of estimating whale abundance could be established based on data of the habitat selections of each whale species (Watanabe et al. 2012b).

In this document, we firstly report the habitat selection of sei (*Balaenoptera borealis*) and Bryde’s whales (*B. edeni*), which are abundant baleen whales in the North Pacific (Fujise et al. 2004, Kasamatsu et al. 2009), in relation to ecosystem information in the boundary zone of sub-area 8 and 9 in late summer. This area is characterized as typical offshore region of the western North Pacific and also the most eastern area where small epipelagic fish and squid species, such as Japanese anchovy *Engraulis japonica*, Japanese sardine *Saldinops melanostictus*, Japanese common mackerel *Scomber japonicus*, and Japanese common squid *Todarodes pacificus*, which migrate into this area from Japanese waters, are commonly found in summer. Hence this area is suitable to study habitat and prey selections of each whale species in relation to various prey environments and we attempt to research in this area in various seasons (Watanabe et al. 2011, 2012a, 2012b).

During cooperative survey period of whale sighting, prey species, and whale sampling in this year, a total of 24 individuals of Bryde's whale was captured (Bando unpubl. data). Using these data, functional relationship and prey preference of Bryde's whale in relation to its distribution pattern will be analyzed in the future.

MATERIALS AND METHODS

We conducted whale sighting and prey surveys in the western North Pacific enclosed by latitude from 36˚30'N to 45º30'N and longitude from 156ºE and 159ºE from 28 July to 15 August 2012 by the R/V Shunyo Maru (887 GT, National Research Institute of Far Seas Fisheries, Fig. 1). Cooperate survey of Shunyo Maru, Nisshin Maru, and two whale sampling vessels were conducted on the southern track line from 38˚N to 39˚30'N during 28-30 July (Fig. 1). During cooperative survey period, all surveys were conducted within 0 to 6 days. Followings were detail of whale sighting and prey survey methods for each survey item. Relationship between these survey items and outputs and goals of this study are summarized in Fig. 2.

(1) Whale sighting survey

Whale sighting survey was carried out along with acoustic survey (see below) basically in passing mode when wind velocity was less than 10 knots and visibility was more than two nautical miles (Fig. 2). However, abeam closing survey was also conducted within two nautical miles perpendicular to track line in case that the species of cetaceans could not identified by passing mode (Kasamatsu et al. 2009). During the survey, two primary observers were allocated to the top barrel. This survey was conducted during the daylight period from one hour after sunrise to one hour before sunset and a total of 812 nautical miles was searched. A total of 187 animals of 100 schools of large cetacean species, including Bryde's, sei, and sperm whales was found by primary sighting (Table 1).

(2) Survey of oceanographic conditions

A Conductivity–Temperature–Depth (CTD, Sea–Bird Co., Ltd.) profiler cast was made down to 500 m depth at each sampling station and additional stations to determine the position of the subarctic boundary and subarctic front (Fig. 2 and Table 2).

(3) Fluorescence survey and water sampling

We conducted fluorescence survey using the fluorometer ACL-208DK (JFE advance) in the 0–150 m layer once a day during 11:00 AM to 1:00 PM in local time to obtain data on geographical distribution of primary production in the epipelagic zone of this study area (Fig. 2 and Table 3). We also conducted water sampling by Niskin bottles in 0, 10, 30, 50, and 100 m depths at the same position where fluorescence survey was conducted and several additional stations to estimate primary production in each size range of phytoplankton (< 0.7 μm, 2-10 μm, and > 10 μm) in epipelagic zone and also to calibrate fluorescence value obtained by fluorometer. All water samples were successively filtered by Whatman GF/F (0.7 μm) and two nuclepore filters (2 and 10 μm, Table 4). These filters were frozen at -80ºC aboard the ship for future analysis in the laboratory ashore.

(4) Twin NORPAC net sampling

We conducted twin NORPAC net samplings in the 0–150 m layer to collect data for species and size compositions of small and meso- zooplanktons, especially copepods, in epipelagic zone (Fig. 2 and Table 5). The mouth opening of this net was 0.15 m^2 and the mesh size of each net was 0.01 x 0.01 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.

(5) BONGO net sampling

BONGO net was towed to examine species and size compositions of macro zooplanktons, especially euphausiids like *Euphausia pacifica* (Fig. 2). The mouth opening and mesh size of this net were 0.28 m^2 and 1.0 x 1.0 mm, respectively. BONGO net was towed at 2 knots in the target depths for 10 to 40 minutes (Table 6). A flow meter was attached to net mouth to measure the volume of seawater filtered. We selected target depths using information of DSL and patchiness in the echograms of 38, 70, and 120 kHz. Samples were preserved in 5 % formalin–buffered seawater for later analysis.

(6) 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 (PI 32, SIMRAD). Trawl samplings were made to identify species and size compositions of small epipelagic fish-like acoustic backscatters in the echosounders and also aimed for collecting distribution data on species difficult to detect by the echosounders such as squids and neustonic organisms like Pacific saury (Fig. 2). Trawling station was predetermined at generally every 30 to 50 nautical mile apart on the track lines. At each station, a trawl net was towed at the target depth between 0 and 200 m for 30 to 60 minutes. 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. 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. In this year, a total of 11 times of midwater trawl survey was conducted (see Fig. 3).

(7) Quantitative echosounder survey

We collected acoustic data by quantitative echosounders SIMRAD EK60 with operating frequency at 38, 70, and 120 kHz by sailing at 10 knots on the track lines (Fig. 2). Calibrations of the echosounders were carried out in the coastal region off western Izu Peninsula (35˚02’N, 138˚51’E) on 20 and 21 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 by SonarData Echoview (Sonar Data Co., Ltd.) software.

During the cruise, communication between control PC on the bridge and the 38 kHz transceiver unit (GPT) of EK60 system broke down at 09:43 (ship mean time = Japan standard time + 1h), on 9 August. It was found later that malfunction of a communication module of the GPT had happened. After the malfunction of 38 kHz, we are obliged to use 70 kHz and 120 kHz instead of the usual combination of 38 kHz and 120 kHz to classify euphausiids. And also 70 kHz instead of 38 kHz will be used to estimate abundance of small epipelagic fish species such as Japanese anchovy, Japanese sardine, and Japanese common mackerel in the future.

(8) Noise and sailing loss measurements

Generally, noise of the ship and sailing loss significantly affect to quantitative analysis on distribution density of marine organisms based on acoustic data. Hence we measured noise and sailing loss of Shunyo Maru as follows.

Nose measurement was conducted on 13 August in various ship speeds to estimate the most suitable ship speed in relation to acoustic survey. Because Shunyo Maru equipped fishing and whale sonars, and we preliminary used these sonars in this year, noise measurement was also carried out in relation to the protrusion and retraction of these sonars. During this experiment, engine revolution was kept at 550 rpm when two engines were used and the angle of the propeller was changed to keep the ship speed.

Sailing loss was checked on 19 August using the reflection from sea bed on the transect line, which was set between the positions of 34º58'N, 138º45'E and 34º55'N, 138º45'E along the coastal region off western Izu Peninsula. The effects of protrusion and retraction of fishing and whale sonars were investigated by measuring acoustic volume backscattering strengths (SVs) of the bottom. At first, the vessel was drifted at the northernmost, middle, and southernmost points of the transect line and we measured SV of the bottom echoes at these points. Then bottom echoes were measured on the transect line by moving at 10 knots from the southernmost to the northernmost points and also from the northernmost to the southernmost points. These measurements were conducted firstly without protruding of fishing and whale sonars. Then similar measurement was conducted in case that fishing sonar, whale sonar, and both sonars were protruded. In case that SV level of the bottom decreased when sonars were protruded, we can deem the existence of attenuation of acoustic energy (i.e. sailing loss) accompanied by surrounding air bubbles of protruded sonars.

Using these results, together with the result of trawling survey, acoustic data will be analyzed quantitatively.

(9) Estimate of target strength of zooplanktons

In relation to obtain quantitative information on ecosystem and prey environment of each whale species based on acoustic data, living euphausiids mainly *Euphausia pacifica* were sorted from twin NORPAC or BONGO nets and its sound speed and density contrasts were measured by time of flight method and density bottle method, respectively, aboard the ship (Mikami et al. 2000). These experiments are essential to obtain theoretical values of target strength (TS) of euphausiids, which are important to estimate its biomass by acoustic data (Fig. 2). To calculate TS of euphausiids, the Distorted-Wave Born

Approximation based deformed-cylinder model (DWBA model) will be adopted and dorsal-aspect TS as a function of the incident angle of the ensonified wave (TS-pattern) will be calculated in the future.

RESULTS AND DISCUSSION

Oceanographic conditions

In the northern North Pacific, 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. Subarctic boundary is defined by 34.0 salinity front in the epipelagic zone (Favorite et al. 1976). Our CTD data showed that water temperature at 100 m was higher than 5˚C south of 43˚15'N and vertical salinity front of 34.0 in the epipelagic zone was found in the area between 43˚ and 43˚10'N, indicating that this study area was located in the subarctic region north of ca. 43˚N and the transition zone to the south (Fig. 3B). Because the position of subarctic boundary and subarctic front was almost similar, transitional domain was not clearly recognized in this study.

Distribution of sei and Bryde's whales related to prey environment

Sei whale: This species was found in the northern transition zone and subarctic region between 41˚N and 45˚N in late July-August of this year (Fig. 3B). In this study area, sei whale was reported to be densely distributed in the transition zone south of 39˚N in June (Watanabe et al. 2012a, Fig. 3A), suggesting that this whale species undertake northward migration from early to late summer. Among prey species, Japanese anchovy and Japanese common mackerel, which are the main prey items of the whale in general (e.g. Konishi et al. 2009, Tamura et al. 2012), were abundantly distributed in the main habitat of sei whale in late July-August (Fig. 3B). According to Watanabe et al. (2012a), the main habitat of sei whale was also found in the distribution centre of Japanese anchovy and Japanese common mackerel in June of this study area (Fig. 3A). Because these prey species undertake northward migration from the southern transition zone to the northern region around subarctic front during summer (Pearcy et al. 1996, Ichii et al. 2004), sei whale possibly migrate to the northward following northward migration of these prey species from early to late summer. Body length of Japanese anchovy and Japanese common mackerel shifted from 6 to 9 cm to 8 to 12 cm and from 15 to 18 cm to 18 to 21 cm, respectively, during

June and late July-August (Fig. 3). This probably indicates a growth of 2 to 3 cm in body length over 2 months for these species because daily growth rate of these species are about 0.5 mm (Fisheries Agency of Japan 2002). Therefore, sei whale seems to carry out northward migration with the same cohort of Japanese anchovy and Japanese common mackerel, which probably hatched in early spring, from early to late summer.

Bryde's whale: This species was found in the southern transition zone between 37˚30'N and 39˚30'N in late July-August 2012 (Fig. 3B). Bryde's whale was not distributed in the same study area in June 2011, indicating that this species migrate into this study area from the southern transition zone during mid to late summer (Watanabe et al. 2012a, Fig. 3A). It was remarkable that distributions of Bryde's whale and juvenile Japanese anchovy (mainly 5 to 7 cm in body length) and Japanese sardine (mainly 6 to 8 cm in body length) almost completely overlapped in July-August 2012 (Fig. 3B). These species probably hatched during mid and late spring because daily growth rate of this species is approximately 0.5 mm and also thought to migrate into this study area from the southern transition zone in late summer (Fisheries Agency of Japan 2002). This suggests that sei and Bryde's whale feed mainly on Japanese anchovy of different hatching seasons. According to the result of whale sampling survey in this year, Bryde's whale fed mainly on juvenile Japanese anchovy and Japanese sardine in this study area during cooperative whale sighting, sampling, and prey survey period (Bando unpubl. data). These data suggest that the distribution of these fishes greatly affect to the distribution and/or northward migration of Bryde's whale. Similar results are also obtained in the southern transition zone in sub-area 7 bound by 37-39˚N and 146-148˚E in late July 2008 (Watanabe et al. 2012b), suggesting that distribution pattern of Bryde's whale in relation to prey environment obtained in this study is widely applied to the oceanic region of sub-area 7 and 8 in the western North Pacific from mid to late summer. According to Konishi et al. (2009), Bryde's whale feed mainly on euphausiids in this study area although this whale species rarely migrate into there in early summer. This probably reflects feeding habits of small part of Bryde's whale population which migrate into this study area prier to the main part of the whale population in early summer.

Distribution of sei and Bryde's whales related to primary production

In relation to chlorophyll *a* concentration at 20-30 m depth (CHA), which was measured by a fluorometer adopted in this study, sei whale was mainly distributed in the area of around 0.8 mg m^{-3} CHA in both June and late July-August (Figs. 3 and 4). This depth range is well corresponded to the habitat depth of Japanese anchovy and Japanese common mackerel, which are mainly fed on by sei and/or Bryde's whales (Konishi et al. 2009, Watanabe, Bando, and Tamura unpubl. data). The main prey species of the whale, Japanese anchovy (5-8 cm in body length in June and > 8cm in July-August) and Japanese common mackerel (15-18 cm in body length in June and 18-21 cm in July-August) was also mainly distributed in this CHA area. Both Bryde's whale and its main prey species, Japanese anchovy of 5-7 cm in body length, were mainly distributed in the less productive southern area where CHA was around 0.45 mg m^{-3} in late July-August (Figs. 3 and 4). In this period, no Bryde's whale was found in the southernmost region of the study area where CHA value was < 0.4 mg m^{-3}. This area is one of the most ologotrophic region in any oceanic environment in summer (Cullen 1982), showing unfavourable feeding condition for the whale. In June, both Bryde's whale and CHA area of around 0.45 mg m^{-3} was rarely found in this study area. This CHA area was probably located in the more southern area south of the study area in this period, according to previous reports (e.g. Polovina et al. 2000).

These chlorophyll *a* concentration areas are known to undertake northward migration from spring to summer (Polovina et al. 2000, 2001, Bograd et al. 2004; Baker et al. 2007), as was also shown in this study (Figs. 3 and 4). Because northward migration patterns of sei whale and CHA area of 0.7-0.9 mg m^{-3} and those of Bryde's whale and CHA area of 0.4-0.5 mg m^{-3} were spatio-temporally similar to each other, distributions and seasonal south-north migrations of these whale species seems to be related to primary production (Fig. 4). This probably indicates that distributions of these whale species is also closely related to biological productivity, since Japanese anchovy and Japanese common mackerel are planktivorous (e.g. Takahashi et al. 2001) and distribution of these species might be closely related to the secondary production. To evaluate this hypothesis, analysis on geographical distribution and abundance of zooplankton is badly needed, which is essential to progress ecosystem modelling including whales in JARPN II area. Similar knowledge on relationship between distribution of large sized predator and primary production are also obtained for many other species such as swordfish *Xiphias gladius*, albacore *Thunnus alalunga*, neon flying squid *Ommastrephes bartramii*, and Pacific pomfret *Brama japonica* (Polovina et al. 2001, Seki et al. 2002, Ichii et al. 2004, Baker et al. 2007, Watanabe et al. 2004, 2006, and 2009).

Distribution of sei whale related to physical environments

Distribution area of sei whale was greatly changed from June to late July-August in terms of temperature above 10 m and below 40 m in 0-200 m layer at the sighting position of this species (Fig. 5a). However, temperature range at 20 and 30 m in the habitat of sei whale was almost similar and approximately 12 to 16˚C between June and late July-August, suggesting that this whale species undertake northward migration following northward migration of these isotherms at these depths during summer. This probably caused by densely distribution of Japanese anchovy and Japanese common mackerel preys in this temperature range at 20-30 m (Watanabe unpubl. data, see also Fig. 3). These results also suggest that distribution of sei whale could be estimated by distribution of isotherms at sub-surface layer, which is essential to estimate abundance of the whale in the area where whale sighting survey could not be conducted.

Contrasting with temperature, salinity values in each depth layer of sighting position of sei whales were generally smaller in June than in late July- August (Fig. 5b). This reflects that main habitat of sei whale shifts from the southern transition zone to the area in or close to the subarctic region from June to August, because salinity in the epipelagic zone generally decrease from the subarctic region to the south (Favorite et al. 1976, Pearcy 1991, Roden 1991). Therefore, salinity seems to be unusable to estimate summer distribution of this species.

Noise and sailing loss measurements

The result of nose measurement showed that noise SVs at 120 kHz were relatively low and stable regardless of ship conditions and protrusion and retraction of the two sonars (-75 to -80 dB, Table 7). In case of 70 kHz, however, noise SVs greatly fluctuated in several cases. When both sonars were protruded (see No. 7 and 8 in Table 7), noise SVs at 70 kHz were almost similar to each other (-79.7 vs. -80.9 dB). However, these values were about 8 dB higher than the case that both sonars were retracted (see No. 11 in Table 7). The present result also indicated that difference in SV values at 70 kHz between the cases that both sonars were retracted (No. 11 in Table 7) and only fishing sonar was protruded (No. 12 in Table 7) was small and similar to each other (-88.5 and -87.8 dB). However, noise SVs at 70 kHz were about 10 dB higher in case that only whale sonar was protruded (No. 13 in Table 7) than the case that both sonars were retracted (No. 11 in Table 7, -78.0 vs. -88.5 dB). These results strongly suggest that acoustic survey using 70 kHz and whale sonar survey should be conducted alternatively on Shunyo Maru.

The result of the sailing loss measurement showed that measured SVs of the bottom during sailing and drifting and during sailing with and without protrusion of the two sonars were similar to each other (Fig. 6). These facts suggest that sailing loss accompanied by protrusion of sonars could not significantly affect to the acoustic data of 70 and 120 kHz collected by Shunyo Maru.

Because communication between control PC on the bridge and the 38 kHz transceiver unit of EK60 system broke down during the cruise, we could not obtain these data for 38 kHz echosounder in this study. Such data is badly needed to obtain quantitative information on ecosystem structure.

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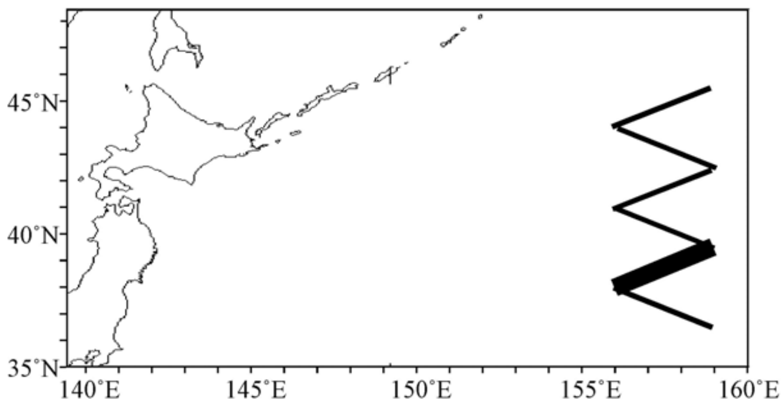

Fig. 1. Research track line of whale sighting and prey surveys conducted in late July-August 2012. Bold line indicates the area where cooperative whale sighting, sampling, and prey surveys were conducted. Cooperative survey was conducted for Bryde's whale.

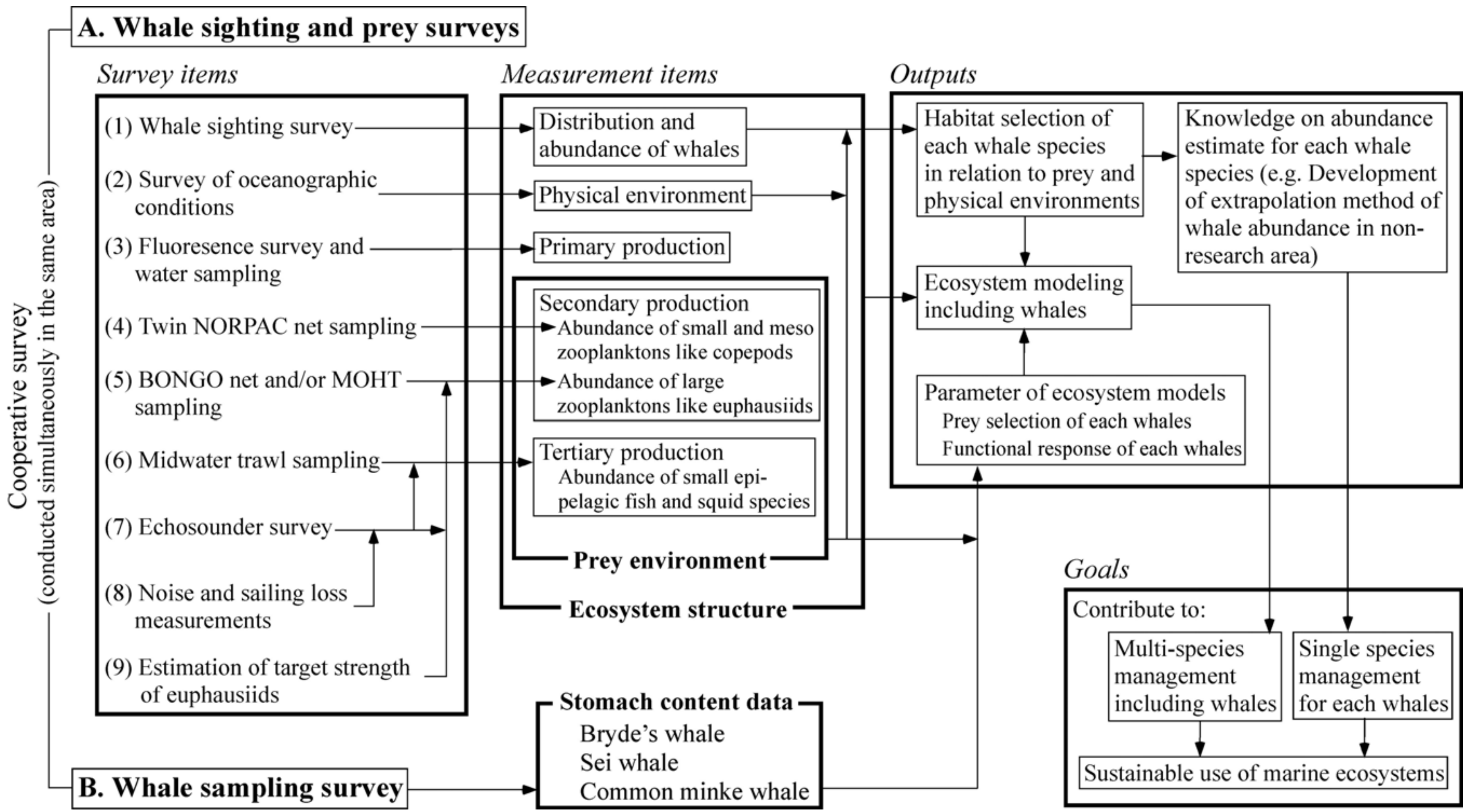

Fig. 2. Survey and measurement items of whale sighting and prey surveys in relation to expected outputs and goals of these surveys. Relationship between these surveys and whale sampling survey was also depicted.

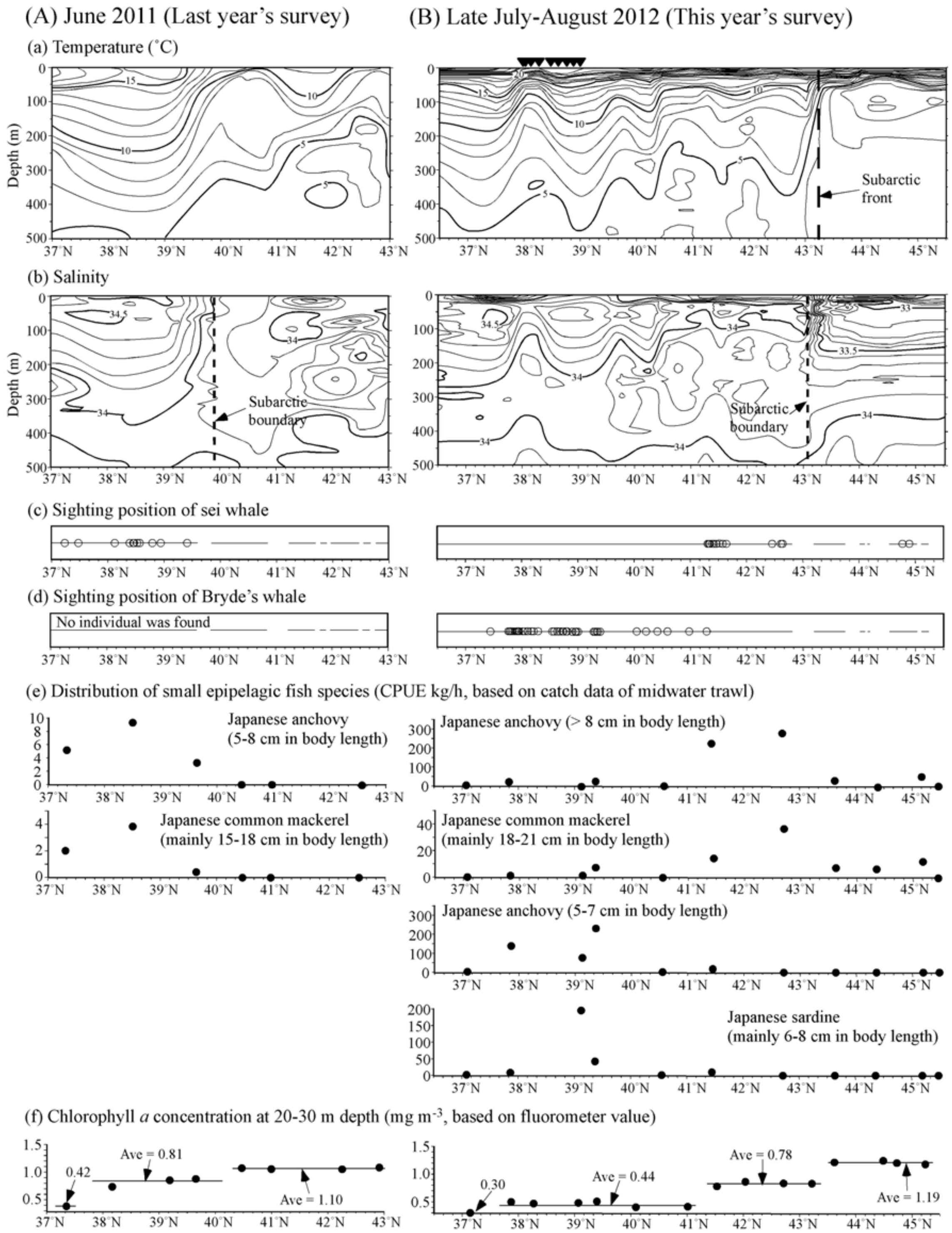

Fig. 3. Vertical temperature and salinity profiles, sighting positions of sei and Bryde's whales, geographical distributions of each small epipelagic fish species, and geographical distribution of chlorophyll *a* at 20-30 m depth along track line in early summer 2011 (last year's survey) (A) and late summer 2012 (this year's survey) (B). Surveys in these two years were conducted in the same geographical areas between 156˚E and 159˚E. ▼: Sampling position of Bryde's whale in 2012 during cooperate whale sighting, sampling, and prey survey period (Bando unpubl. data).

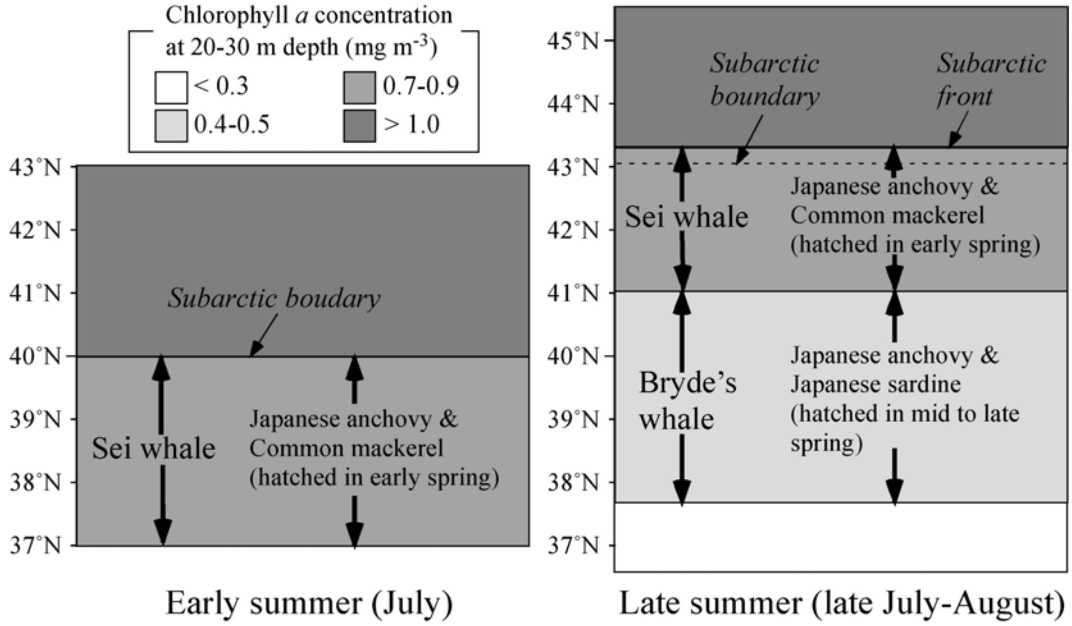

Fig. 4. Distribution and south-north migration pattern of sei and Bryde's whales and their prey species in relation to primary production and oceanographic fronts in early (June) and late summers (late July-August) in the boundary zone of sub-area 8 and 9. A thick arrow indicates range of the main habitat of each predator and prey species in relation to latitude.

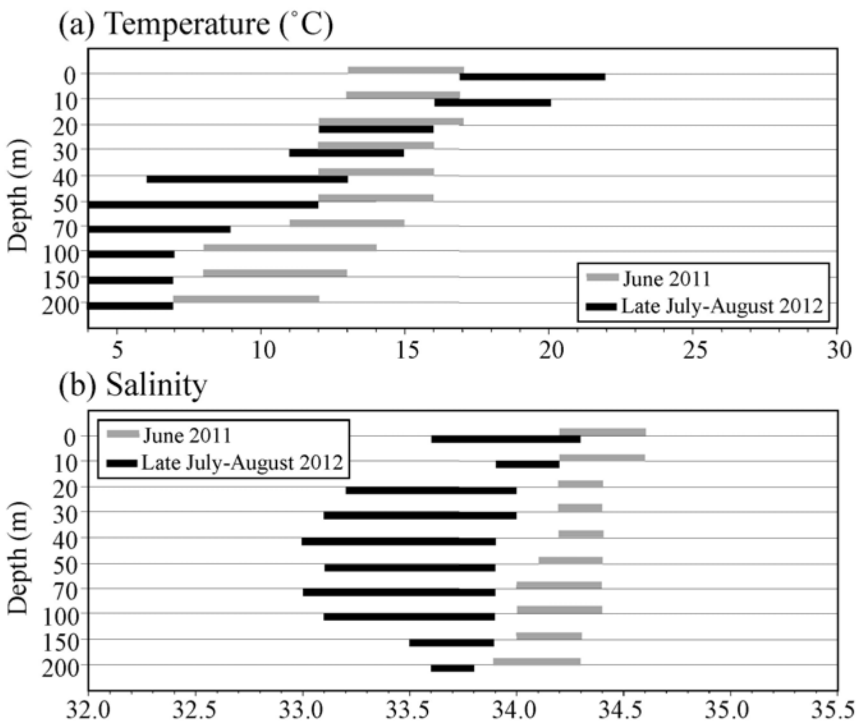

Fig. 5. Temperature and salinity ranges of each depth layer in epipelagic zone at the position where sei whale was sighted in June 2011 (last year's survey) and late July-August 2012 (this year's survey).

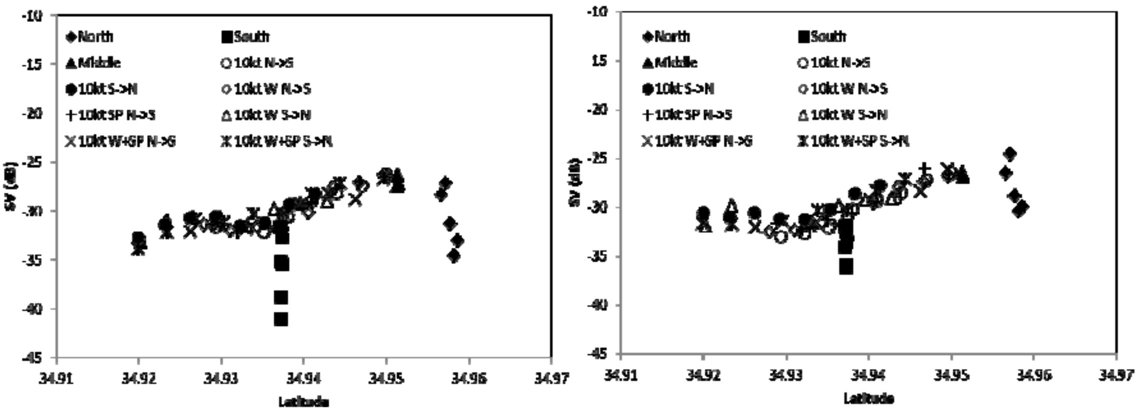

Fig. 6. Acoustic volume backscattering strength (SV) in the bottom at 70 (left) and 120 kHz (right). Diamonds, triangles, and squares indicate 5 minutes integration values during drift period of the vessel at the northernmost, middle, and southernmost points of the transect, respectively. Each symbol denotes measured SV with protrusion of fishing and/or whale sonar and without protrusion. SP: the protrusion of fishing sonar; W: the protrusion of whale sonar; W+SP: the protrusion of both sonars. ‘N→S’ indicates a sailing from northern to southern area on the transect. ‘S→N’ indicates a sailing from southern to northern area on the transect.

Table 1. Results of sighting survey for large cetaceans in late July-August 2012.

Species	Schools	Inds
Bryde's whale	58	72
Sei whale	15	19
Sperm whale	27	96
Total	100	187

Table 2. Date and positions of CTD cast station in 2012.

			Latitude (N)		Logitude (E)					Latitude (N)		Logitude (E)	
Stn	Month	Day	Degree	Minute	Degree	Minute	Stn	Month	Day	Degree	Minute	Degree	Minute
1	7	28	38	7	156	15	21	8	7	41	31	157	0
2	7	28	38	19	156	37	23	8	8	42	2	158	3
3	7	28	38	37	157	16	24	8	8	42	16	158	25
4	7	29	39	4	158	7	25	8	9	42	42	158	38
5	7	29	39	17	158	25	27	8	9	42	55	158	10
6	7	30	39	27	158	49	28	8	10	43	14	157	54
7	7	30	39	44	158	31	30	8	11	43	33	156	55
8	7	31	37	55	156	18	31	8	11	43	49	156	39
9	7	31	37	42	156	39	32	8	12	45	41	159	2
10	8	1	37	9	157	43	33	8	12	45	18	158	32
11	8	1	37	11	157	54	35	8	13	45	16	158	11
12	8	2	36	43	158	34	37	8	14	44	44	157	29
13	8	2	37	11	157	48	38	8	14	44	30	156	60
14	8	3	40	10	157	42	39	8	15	44	29	156	43
16	8	4	40	27	156	52	40	8	15	43	58	156	5
17	8	5	41	1	156	2	41	8	19	35	2	138	51
18	8	5	41	17	156	34							

Table 3. Research data of fluorescence survey in 2012.

			Latitude (N)		Logitude (E)	
Stn	Month	Day	Degree	Minute	Degree	Minute
2	7	28	38	19	156	37
4	7	29	39	4	158	7
6	7	30	39	27	158	49
8	7	31	37	55	156	18
10	8	1	37	9	157	43
14	8	3	40	10	157	42
15	8	3	40	12	157	46
21	8	7	41	31	157	0
23	8	8	42	2	158	4
25	8	9	42	42	158	37
28	8	10	43	14	157	55
30	8	11	43	33	156	55
32	8	12	45	41	159	2
35	8	13	45	16	158	11
37	8	14	44	44	157	29
39	8	15	44	29	156	43

Table 4. Volume of water filtered (ml) in each depth layer of each station in late July-August 2012. Locality of each station was described in Tables 2 and 5.

Depth	St No.																
(m)	2	4	6	8	10	12	14	17	21	23	25	28	30	32	35	37	39
0	196	195	205	210	220	225	210	235	225	240	200	250	215	215	250	250	220
10	207	205	227	155	215	-	205	-	250	220	255	255	250	225	240	260	230
30	165	240	260	200	220	-	195	-	240	240	225	250	245	240	245	260	245
50	195	170	210	190	235	-	180	-	240	255	220	245	220	235	260	255	240
100	205	250	260	190	230	-	235	-	230	250	195	230	250	245	240	250	245

Table 5. Sampling data of twin NORPAC net in 2012.

			Latitude (N)		Logitude (E)					Latitude (N)		Logitude (E)	
Stn	Month	Day	Degree	Minute	Degree	Minute	Stn	Month	Day	Degree	Minute	Degree	Minute
1	7	28	38	7	156	14	21	8	7	41	31	157	0
2	7	28	38	19	156	37	23	8	8	42	2	158	4
3	7	28	38	37	157	16	24	8	8	42	16	158	25
4	7	29	39	4	158	8	25	8	9	42	42	158	37
5	7	29	39	17	158	25	27	8	9	42	55	158	10
6	7	30	39	27	158	49	28	8	10	43	14	157	55
7	7	30	39	43	158	31	30	8	11	43	33	156	56
8	7	31	37	55	156	18	32	8	12	45	41	159	2
9	7	31	37	43	156	40	33	8	12	45	18	158	33
10	8	1	37	10	157	43	35	8	13	45	16	158	11
12	8	2	36	43	158	33	37	8	14	44	43	157	29
14	8	3	40	10	157	42	38	8	14	44	31	157	0
16	8	4	40	27	156	52	39	8	15	44	29	156	43
17	8	5	41	1	156	2	40	8	15	43	58	156	5
18	8	5	41	17	156	34							

Table 6. Sampling data of BONGO net in 2012.

			Latitude (N)		Logitude (E)		Sampling	Sampling
Stn	Month	Day	Degree	Minute	Degree	Minute	depth (m)	duration (min)
9	7	31	37	40	156	40	80	35
11	8	1	37	1	157	60	200	30
11	8	1	37	4	157	58	30	30
11	8	1	37	6	157	57	440	30
13	8	2	37	5	157	48	80	39
13	8	2	37	8	157	47	50	30
15	8	3	40	9	157	43	240	30
15	8	3	40	12	157	46	30	30
17	8	5	41	1	156	2	230	40
19	8	6	41	21	156	35	120	30
31	8	11	43	46	156	37	170	30
33	8	12	45	15	158	30	220	30
36	8	13	45	6	158	13	220	40
37	8	14	44	44	157	29	20	10
37	8	14	44	44	157	29	30	10
37	8	14	44	45	157	29	0-190	-

Table 7. Average values of measuring acoustic volume backscattering strength (SV) in the 300-350 m depth in the various conditions of engine, sonars (protrusion or retraction), and relative wind direction. R.P.M.: Rotation per minutes; One: one engine was used; Two: two engines were used; P: protruded; N: non-protruded. All surveys were conducted in the daylight period.

No.	Engine	Ship speed	Engine	Propellar angle	Whale	Fishing Sonar	Wind	Avg. SV (dB) in 300-350 m depth	
		(kt)	R.P.M.	(deg)	sonar	Sp-70	dir.	70 kHz	120 kHz
1	Two	Clutch out	550	-	P	P	Side	-88.8	-75.9
2	Two	Clutch in	550	-	P	P	Side	-88.7	-75.7
3	Two	8	550	16.7	P	P	Side	-83.9	-78.1
4	Two	8	550	16.7	P	P	Side	-84.6	-77.7
5	Two	9	550	18.2	P	P	Side	-82.7	-78.3
6	Two	9	550	18.2	P	P	Side	-81.9	-78.8
7	Two	10	550	21.5	P	P	Side	-79.7	-79.3
8	Two	10	550	21.5	P	P	Side	-80.9	-79.2
9	Two	11	550	23.6	P	P	Side	-78.8	-79.0
10	Two	11	550	23.3	P	P	Side	-78.2	-78.7
11	Two	10	550	18.4	N	N	Side	-88.5	-76.1
12	Two	10	550	19.2	N	P	Side	-87.8	-76.3
13	Two	10	550	20.7	P	N	Side	-78.0	-77.2
14	Two	10	550	17.1	N	N	Follow	-88.2	-76.1
15	One	8	650	12.3	N	N	Side	-83.6	-77.6
16	One	8	650	12.3	N	N	Side	-82.6	-77.7