Cruise Report of the Second Phase of the Japanese Whale Research Program under Special Permit in the Western North Pacific (JARPN II) in 2011 (part I) – Offshore component –

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ABSTRACT

The tenth 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 prey species survey. A total of five research vessels was used: two sighting/sampling vessels (SSVs) (whale sampling survey component), one research base vessel (whale sampling survey component), one whale prey survey vessel equipped with scientific echo sounder (PSV) (whale prey survey component) and three dedicated sighting vessels (SVs) (dedicated sighting survey component), The whale sampling survey was carried out from 11 June to 5 September 2011. A total of 5,156 n.miles was surveyed in a period of 76 days by the SSVs. A total of 53 common minke, 476 sei, 149 Bryde's, 295 sperm, 66 fin and eight blue whales were sighted by the SSVs and *NM*. A total of 49 common minke, 95 sei, 50 Bryde's and one sperm whale was sampled by the SSVs. All whales sampled were examined on board the research base vessel. In July, common minke whales fed mainly on Japanese anchovy near Syiriya, and they fed mainly on walleye pollock around east of Hokkaido. There were geographically changes of prey species of minke whales in sub area 7. Sei whales fed mainly on copepods and Japanese anchovy from June to August in sub areas 8 and 9. Bryde's whales fed mainly on krill in sub area 7 in July. There were yearly changes of prey species of Bryde's whales in sub area 7. Dominant prey species in the stomach of the sperm whale were various kinds of squids, which inhabit the mid- and deep-waters. The dedicated sighting surveys were carried out from 28 April and 6 June in 2011. Surveys were conducted in the sub areas 8 and 9. A total of 4,060 n.miles was surveyed by the SVs. A total of three common minke, 51 sei, six Bryde's, 116 sperm, 31 fin and four blue whales were sighted. The prey species survey was carried out from 13 to 28 June in 2011. Surveys were conducted in a part of sub areas 8 and 9 by the PSV. Distribution and/or abundance of the whales and its prey species were investigated. The purpose of this survey was to estimate habitat and prey preference of sei whale in relation to oceanographic and prey environments as well as productivity in early 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 PERMITS

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 prey species survey.

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 Independent Expert Panel (IEP). Constructive discussions were conducted and some recommendations were offered by the IEP. Some of those recommendations were already responded by Japanese scientists.

This paper reports the tenth full-scale survey of the JARPN II -offshore component-, carried out in 2011.

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 of the SSV vessels (Figure 1).

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.

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; 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 both for the whale sampling survey, dedicated sighting survey and whale prey species 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; 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 *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 two n.miles or more and wind force of four 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 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 2011 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)), 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 SSV vessels and the *NM*:

1. Sighting distance and angle experiments to examine the precision of sighting data (*YS1* and *YS2*).
2. Biopsy sampling on gray, blue, fin, humpback and right whales (*YS1* and *YS2*).

3. Photographic records of natural marks on blue, humpback and right whales (*YS1* and *YS2*).
4. Feeding behaviour patterns of large whale species (blue, fin, sei, Bryde's, common minke, humpback, right and sperm whales) (*YS1* and *YS2*).
5. Excretion and vomiting behaviour patterns of large whale species (sei, Bryde's, common minke and sperm whales) (*YS1* and *YS2*).
6. Marine debris observation during transit (*NM)*. Record of large marine debris in the research area (*YS1*, *YS2* and *NM*), which were expected to be frequent after the earthquake and tsunami that affected Japan in March 2011.

Dedicated Sighting survey (see Matsuoka *et al.*, 2012)

A report of the dedicated sighting surveys was presented by Matsuoka *et al*. (2012). In this document, the summary of these surveys was described.

Research area

The dedicated sighting surveys were set in sub areas 8 and 9.

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. A detailed report of this survey was presented in Document SC/64/O6.

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, 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).
5. Marine debris observation as explained above.

Whale prey species survey (see Appendix 1)

A report of this whale prey species survey was presented in Appendix 1. In this section, the summary of the survey was described. The objective of the survey was to examine habitat and prey preference of sei whale in early summer.

Research area

The whale prey species survey was set in sub area 8 and 9.

Research vessel

The *Hokko Maru* (*HK*: 1,246GT) was used as whale prey species survey vessel (PSV).

Methods for setting cruise track line and survey procedure

The survey was conducted concurrently at the same track line of whale sampling survey within 15 hours in 2011. It was conducted the whale prey species survey by Conductivity–Temperature–Depth (CTD), water irradiance, midwater trawl, Matsuda–Oozeki–Hu–Trawl (MOHT, Oozeki et al. 2004), North Pacific Standard (NORPAC) nets, and quantitative echosounder. To estimate relationship between distribution of each whale species and environmental and biological parameters, whale sighting survey from upper bridge was also conducted by *HK*. A detail report of this survey was presented in Appendix 1 in this paper.

Experiments

The following experiments were conducted by the PSV,

1. Sighting of cetaceans from upper bridge.
2. Observations of oceanographic conditions and biological productivity by the Conductivity–Temperature–Depth (CTD), chlorophyll, and underwater irradiance surveys Oceanographic observations using Conductivity–Temperature–Depth (CTD) and water irradiance.
3. Estimation of abundance of prey species using an echo sounder system as well as mid-water trawl, MOHT and twin NORPAC nets.

RESULT

Whale sampling survey

Actual survey periods, track lines and searching distances

Cruise period: Between 11 June and 5 September (87 days)

Research period: Between 16 June and 30 August (76 days)

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

Searching distance: The total searching distance for SSVs was 5,156 n.miles

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

A total of 52 schools (53 individuals) of common minke whales was sighted, consisting of 14 schools (14 individuals) of primary and 38 schools (39 individuals) of secondary sightings. For sei whale, 198 schools (476 individuals) were sighted, consisting of 46 schools (63 individuals) of primary sightings and 152 schools (413 individuals) of secondary sightings. For Bryde's whale, 122 schools (149 individuals) were sighted, consisting of 77 schools (98 individuals) of primary sightings and 45 schools (51 individuals) of secondary sightings. For sperm whale, 181 schools (295 individuals) were observed, consisting of 135 schools (231 individuals) of primary sightings and 46 schools (64 individuals) 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 (7 schs./8 inds.), fin (52 schs./66 inds.), and humpback whales (11 schs./15 inds.).

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

A total of 49 common minke whales (Male: 38 individuals, Female: 11 individuals), 95 sei whales (Male: 54 individuals, Female: 41 individuals), 50 Bryde's whales (Male: 20 individuals, Female: 30 individuals) and one female

sperm whales were sampled. Struck and lost occurred in one case (sei whale) in this research. Table 2 summarizes the biological data and samples collected from whales. A total of 36 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 and Bryde's whales are shown in Table 3. Statistics of body length of common minke, sei, Bryde's and sperm whales is shown in Table 4. Mean body length of common minke whales was 6.98m and 7.33m for males and females, respectively. For sei whales, those were 13.42m and 13.87m for males and females, respectively. For Bryde's whales, those were 11.65m and 12.00m for males and females, respectively. For sperm whales of females, body length was 10.15m.

Geographical distribution of common minke, sei, Bryde's and sperm whale samples are shown in Figure 3 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 Japanese anchovy (*Engraulis japonicus*) (68.1%) and walleye Pollock (*Theragra chalcogramma*) (17.0%) (Table 5). In this research, almost common minke whales were sampled in the sub-area 7. In July, minke whales fed mainly on Japanese anchovy near Syiriya, and they fed mainly on walleye pollock around east of Hokkaido.

Sei whales were distributed widely in the offshore area. In this survey, almost sei whales were sampled in the sub-areas 8 and 9, they fed mainly on copepods (58.0%) and Japanese anchovy (23.2%) (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-area 7, they fed on krill (71.0%) and Japanese anchovy (29.0%) in July (Table 5).

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

Experiments

Sighting distance and angle experiment

A sighting distance and angle experiment was performed on 28 and 27 June 2011 by *YS1* and *YS2*, respectively. The results of this experiment will be used in calculation of abundance estimates.

Photo-ID and biopsy sampling

Three blue whales were photographed by the SSVs. A total of three biopsy samples were collected from two blue and one Bryde's whales by the SSVs.

Feeding behaviour

No case was observed in the research.

Observation of marine debris

A total of 17 fisheries boats, two large containers, one fishing gear and one other large object were observed and reported to the Japan Maritime Safety Agency and Fisheries Agency. In addition to these, several other marine debris such as refrigerators, lumber, parts of fishing gear, rubble etc. were seen in all research area. The large numbers of debris observed were due to earthquake and tsunami.

Dedicated Sighting survey (see Matsuoka *et al*., 2012)

Actual research periods and searching distance

Cruise period:

YS1, *YS2*: Between 28 April and 6 June (40 days)

YS3 : Between 13 May and 6 June (25 days)

Research period:

YS1, *YS2*: Between 5 May and 31 May (27 days)

YS3 : Between 17 May and 31 May (15 days)

Searching distance:

YS1: 1,466.0 n.miles.

YS2: 1,492.8 n.miles.

YS3: 1,101.5 n.miles.

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

A total of three schools (three individuals) of common minke whales was sighted, consisting of three schools (three individuals) of primary sighting. For sei whale, 32 schools (51 individuals) were sighted, consisting of 31 schools (50 individuals) of primary sighting and one school (one individual) of secondary sighting. For Bryde's whale, three schools (six individuals) were sighted, consisting of three schools (six individuals) of primary sighting. For sperm whale, 60 schools (116 individuals) were observed, consisting of 56 schools (112 individuals) of primary and four schools (four individuals) of secondary sighting.

Sightings of other large cetacean species

Large baleen whales such as blue (four schools/four individuals), fin (23 schools/31 individuals), humpback (27 schools/35 individuals), and right whales (13 schools/20 individuals) were sighted.

Experiments

Photo-ID and biopsy sampling

Three blue, five humpback and 19 right whales were photographed by the SVs. A total of 20 biopsy samples were collected from two blue, two fin, two humpback and 14 right whales by the SVs.

Feeding behaviour

No case was observed in the research.

Observation of marine debris

One fisheries boat was observed and reported to the Japan Maritime Safety Agency.

Whale prey species survey (see Appendix 1)

Actual research period and searching distance

Cruise period: Between 13 and 28 June (16 days)

Research period: Between 16 and 23 June (8 days)

Searching distance: 592 n.miles.

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

A total of 24 schools (27 individuals) of sei whales was sighted, consisting of 19 schools (24 individuals) of primary and two schools (three individuals) of secondary sightings. For sperm whale, three schools (four individuals) of primary sighting were observed.

Sightings of other large cetacean species

No other large whale species were observed.

Experiments

Midwater trawl: Six points

MOHT survey: Six points

MOCNESS net sampling: Two points

NORPAC net sampling: Eight points

DISCUSSION

Prey species and food habits of common minke, sei, Bryde's and sperm whales in the 2011 survey is discussed below in the context of previous survey results.

Common minke whale

From the JARPN and JARPN II surveys from 1994 to 2010, 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 (Tamura *et al*., 2009c).

In the 2011 survey, it was confirmed that walleye pollock is an important prey species for minke whales around east of Hokkaido during feeding season (From April to October), which was also confirmed by the coastal surveys (Yasunaga *et al*, 2012; Kishiro *et al*. 2012). Minke whales fed mainly on Japanese anchovy near Syiriya. In 1980's, their dominant prey was Japanese sardine (*Sardinops melanostictus*) around Sanriku region (Kasamatsu and Tanaka, 1992). After depletion of Japanese sardine resources in late of 1980's, minke whales switched their dominant prey from Japanese sardine to Japanese anchovy in early summer. It is reasonable to assume that minke whales do not have a strong preference for a particular prey species, changes in the prey of minke whales probably reflect changes in the abundance of available prey species in this area.

Sei whale

From our research results of past JARPN II (2000 to 2010), they fed on Japanese anchovy and copepods dominantly during survey season in most of years (Tamura *et al*., 2009c). According to the result of prey species survey conducted in early summer in sub-areas 8 and 9 in the present survey, sei whales were found mainly in the transition zone south of the subarctic boundary where Japanese anchovy was significantly abundant. Sei whales were less frequent in the adjacent areas including both transition zone and transitional domain. These results suggest that sei whales occur at the distribution centre of Japanese anchovy in early summer in sub-areas 8 and 9 (main feeding habit).

Bryde's whale

From our research results of past JARPN II (2000 to 2010), 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 in August, oceanic lightfish were also important prey species. In previous research, Bryde's whale fed mainly on Japanese anchovy (Tamura *et al*., 2009c).

During the present survey Bryde's whale fed mainly on krill in July in the sub area 7. This result suggested that the Japanese anchovy was not abundant in this area in this year and whales selected krill as their prey species. It is also reasonable to assume that Bryde's whales do not have a strong preference for a particular prey species.

Sperm whale

From our research results of past JARPN II (2000 to 2010), 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 2011 JARPN II survey (no. schools/no. individuals)

Cetacean species	Primary		Secondary		Total	
	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Common minke whale	14	14	38	39	52	53
Like minke whale	0	0	2	2	2	2
Sei whale	46	63	152	413	198	476
Bryde's whale	77	98	45	51	122	149
Sperm whale	135	231	46	64	181	295
Blue whale	5	5	2	3	7	8
Fin whale	33	41	19	25	52	66
Humpback whale	8	11	3	4	11	15

Table 2. Summary of biological data and samples collected during the 2011 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	11	38	49	41	54	95	30	20	50	1	0	1
External body proportion	11	38	49	41	54	95	30	20	50	1	0	1
Photographic recoed and external character	11	38	49	41	54	95	30	20	50	1	0	1
Diatom film recoed	11	38	49	41	54	95	30	20	50	1	0	1
Standaed measurements of blubber thickness (five points)	11	38	49	41	54	95	30	20	50	1	0	1
Detailed measurements of blubber thickness (eleven points)	1	0	1	1	0	1	1	0	1	1	0	1
Body weight	11	38	49	41	54	95	30	20	50	1	0	1
Body weight by parts	1	0	1	1	0	1	1	0	1	1	0	1
Blubber tissues for DNA study	11	38	49	41	54	95	30	20	50	1	0	1
Blubber, muscle, liver and kidney tissues for heavy metal/organochlorines analysis	11	38	49	41	54	95	30	20	50	1	0	1
Blubber, muscle, liver and kidney tissues for various analysis	11	38	49	41	54	95	30	20	50	1	0	1
Tissue for nutritional compornent analysis	1	3	4	3	2	5	4	1	5	0	0	0
Lung tissue for air monitoring	0	8	8	0	10	10	6	0	6	1	0	1
Tissues for various analysis	11	38	49	41	54	95	30	20	50	1	0	1
Tissues for virus test	NA	38	38	NA	54	54	NA	20	20	NA	0	0
Mammary gland; lactation status and measurement	11	NA	11	41	NA	41	30	NA	30	1	0	1
Collection of ovary	11	NA	11	41	NA	41	30	NA	30	1	0	1
Photographic record of foetus	3	1	4	8	10	18	2	8	11*	0	0	0
Foetal sex (identified by visual observation)	3	1	4	8	10	18	2	8	11*	0	0	0
Foetal length and weight	3	1	4	8	10	18	2	8	11*	0	0	0
Foetal blubber tissuyes for DNA study	3	1	4	8	10	18	2	8	11*	0	0	0
Testis weight and histological sample	NA	38	38	NA	52	52	NA	20	20	NA	0	0
Collection of plasma sample	10	35	45	41	52	93	30	20	50	1	0	1
Stomach content, conventional record	11	38	49	41	54	95	30	20	50	1	0	1
Volume and weight of stomach content in each compartment	11	38	49	41	54	95	30	20	50	1	0	1
Stomach contents for feeding study	11	38	49	41	54	95	30	20	50	1	0	1
Record of external parasites	11	38	49	41	54	95	30	20	50	1	0	1
Record of internal parasites	11	38	49	41	54	95	30	20	50	1	0	1
Earplug for age determination	11	38	49	41	54	95	30	20	50	1	0	1
Tympanic bulla for age determination	1	0	1	1	0	1	1	0	1	0	0	0
Maxillally teeth for age determination	0	0	0	0	0	0	0	0	0	1	0	1
Lens for age determination	11	38	49	41	54	95	30	20	50	1	0	1
Largest baleen plate for morphologic study and age determination	11	38	49	41	54	95	30	20	50	1	0	1
Vertebral epiphyses sample	11	38	49	41	54	95	30	20	50	1	0	1
Brain weight	0	0	0	1	0	1	1	0	1	1	0	1
Skull measurements (length and breadth)	11	38	49	41	54	95	30	20	50	1	0	1

*: Including fetus of sex unknown.

Table 3. Sex and sexual maturity composition of whales sampled during the 2011 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	10	27	0	37	3	0	3	4	0	0	7	10	47
	SA8	0	0	0	0	0	0	0	0	0	0	0	0	0
	SA9	1	0	0	0	1	0	0	0	0	0	0	1	2
	Combined	11	27	0	38	4	0	3	4	0	0	7	11	49
Sei	SA7	0	0	0	0	1	0	0	0	0	0	0	1	1
	SA8	4	12	0	16	2	0	3	7	1	0	11	13	29
	SA9	7	31	0	38	0	5	11	1	0	0	17	27	65
	Combined	11	43	0	54	13	0	8	18	2	0	28	41	95
Bryde's	SA7	9	7	0	16	8	1	5	7	0	0	13	21	37
	SA8	1	0	0	1	2	0	0	1	0	0	1	3	4
	SA9	0	3	0	3	1	0	2	3	0	0	5	6	9
	Combined	10	10	0	20	11	1	7	11	0	0	19	30	50
Sperm	SA7	0	0	0	0	0	0	0	0	1	0	0	1	1
	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	0	0	0	0	0	0	1	0	0	1	1

Table 4. Body length (m) of whales sampled during the 2011 JARPN II survey.

Species	Sub area	Male					Female				
		n	mean	S.D.	min	max	n	mean	S.D.	min	max
Common minke	SA7	37	7.04	0.83	5.36	7.90	10	7.32	1.32	4.95	8.72
	SA8	0	NA	NA	NA	NA	0	NA	NA	NA	NA
	SA9	1	4.66	NA	4.66	4.66	1	7.44	NA	7.44	7.44
	Combined	38	6.98	0.90	4.66	7.90	11	7.33	1.25	4.95	8.72
Sei	SA7	0	NA	NA	NA	NA	1	13.57	NA	13.57	13.57
	SA8	16	13.41	0.70	11.95	14.33	13	13.93	0.83	12.54	14.97
	SA9	38	13.42	0.96	9.79	14.82	27	13.86	1.21	11.18	15.97
	Combined	54	13.42	0.89	9.79	14.82	41	13.87	1.08	11.18	15.97
Bryde's	SA7	16	11.57	1.46	8.05	13.31	21	11.89	1.71	7.25	13.94
	SA8	1	10.97	NA	10.97	10.97	3	11.27	1.88	9.68	13.35
	SA9	3	12.31	0.27	12.00	12.52	6	12.76	1.84	9.02	13.74
	Combined	20	11.65	1.34	8.05	13.31	30	12.00	1.74	7.25	13.94
Sperm	SA7	0	NA	NA	NA	NA	1	10.15	NA	10.15	10.15
	SA8	0	NA	NA	NA	NA	0	NA	NA	NA	NA
	SA9	0	NA	NA	NA	NA	0	NA	NA	NA	NA
	Combined	0	NA	NA	NA	NA	1	10.15	NA	10.15	10.15

Table 5. Prey species and stomach contents weight (1st. + 2nd. stomachs) in whales sampled during the 2011 JARPN II survey.

Dominant prey species			N	%	Range of weight (kg)
Common minke whale					
	Krill		6	12.8	4.84 - 76.50
	Fish	Japanese anchovy	32	68.1	6.40 - 97.15
		Pacific saury	1	2.1	33.58 - 33.58
		Walleye pollock	8	17.0	13.34 - 76.35
Sei whale					
	Krill		10	14.5	23.44 - 359.21
	Copepods	Neocalanus spp.	40	58.0	8.74 - 419.65
	Fish	Japanese anchovy	16	23.2	4.30 - 516.67
		Pacific saury	3	4.3	4.50 - 151.00
Bryde's whale					
	Krill		22	71.0	19.10 - 161.12
	Fish	Japanese anchovy	9	29.0	58.60 - 728.52

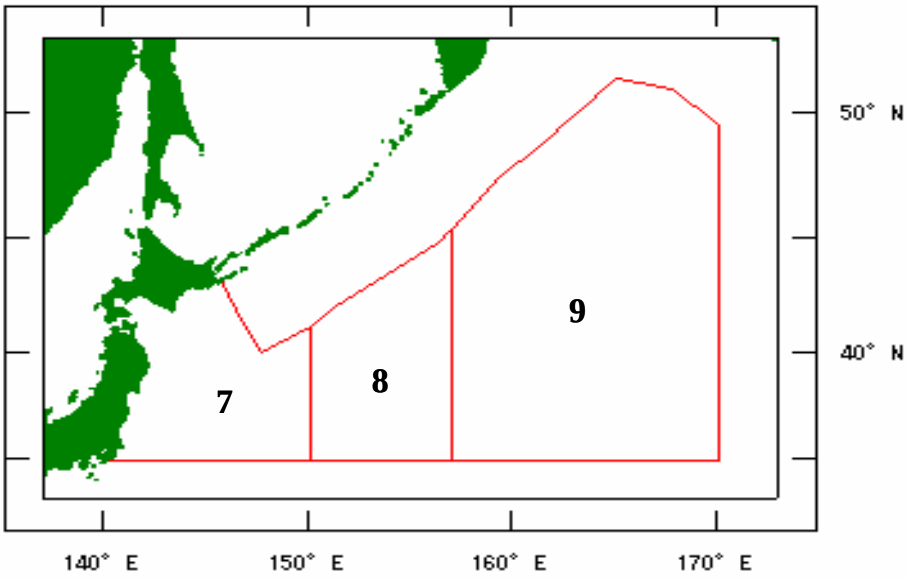

Figure 1. Research area of the JARPN II full-scale program.

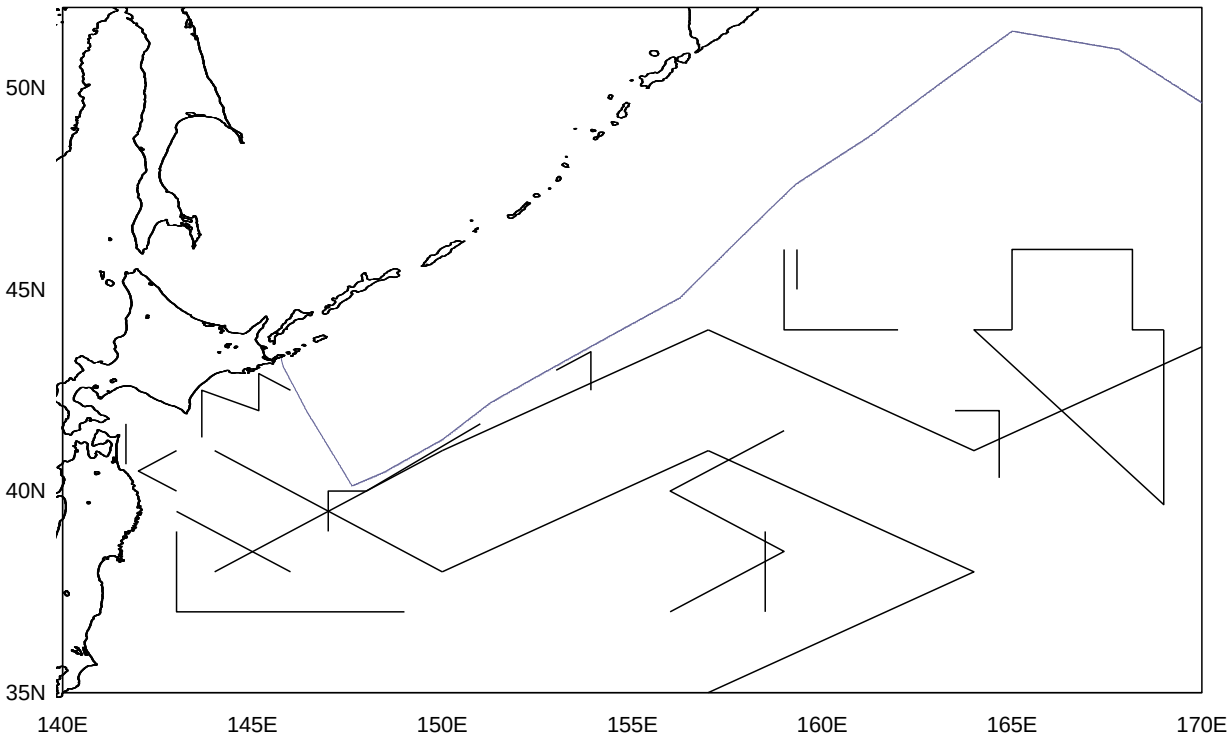

Figure 2. Track-lines of the sighting/sampling vessels (SSVs).

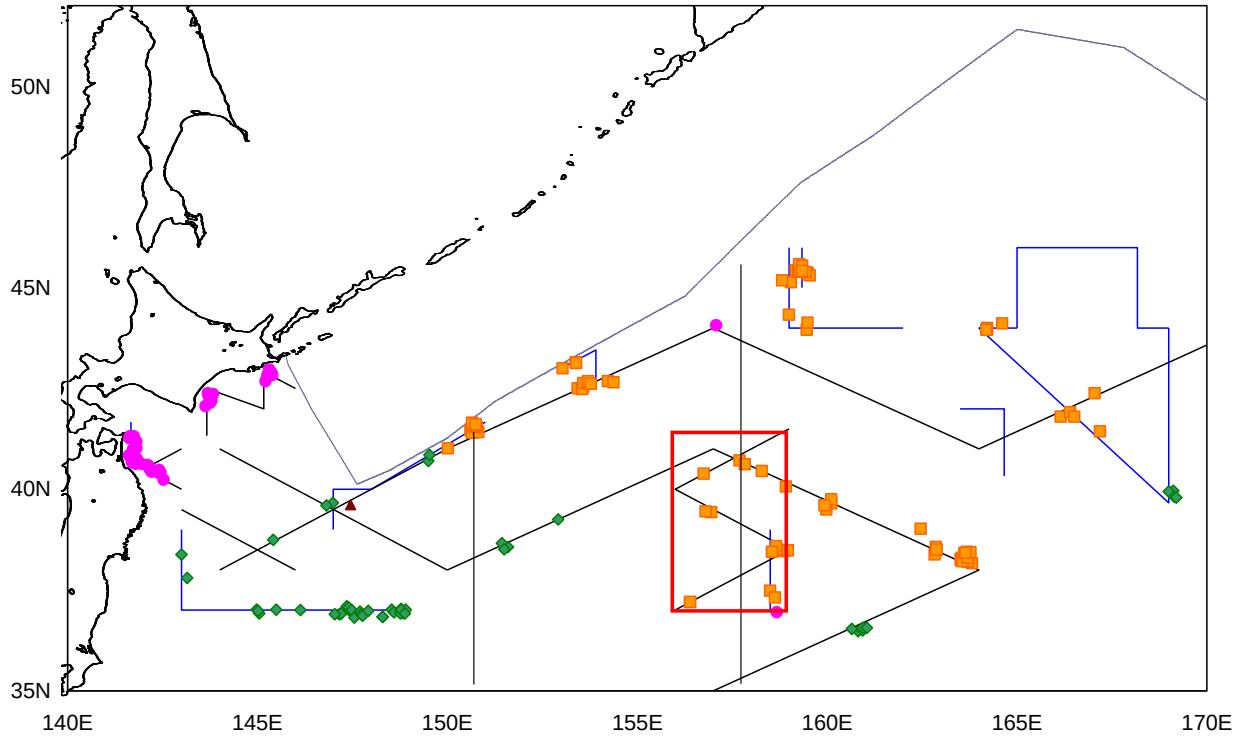

Figure 3. Sighting positions of the sampled common minke (pink circle), sei (orange square), Bryde's (green diamond) and sperm (brown triangle) whales. Red block show the survey area for the cooperative prey and whale sampling survey. Blue lines were special monitoring surveys.

Appendix 1.

Cruise report of JARPN II whale prey species survey in conjunction with whale sampling survey in the offshore region of the western North Pacific in 2011

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ABSTRACT

Whale prey species survey including whale sighting and oceanographic surveys as well as survey of biological productivity was firstly conducted in the transition region of the western North Pacific in a part of sub-areas 8 and 9 in late June 2011. The objective of these surveys in this year were to examine habitat selection of the sei whale Balaenoptera borealis in relation to ecosystem information and also to accumulate quantitative data on functional response and prey preference of the whale in this area in early summer. Hence these surveys were cooperated with the sampling survey of the whale under JARPN II program and all of these surveys were conducted concurrently at the same area within 12 h. Sei whale was mainly found in specific area in the transition zone south of the subarctic boundary where abundance of Japanese anchovy was significantly higher than in its adjacent areas. This area was also corresponded to the area where both primary production and productivity of subtropical copepods, which are thought to the prey of Japanese anchovy, increased about three times comparing with these values in the southern oligotrophic waters. These facts suggest that distribution of sei whale was closely related to biological productivity as well as distribution of their prey species. During cooperative survey period, a total of 14 sei whales was captured. Using stomach content data of these individuals, together with environmental data, functional response and prey preference of the whale will be analyzed in the future.

KEYWORDS: SEI WHALE, HABITAT SELECTION, WHALE SIGHTING AND ECOSYSTEM SURVEYS, OFFSHORE REGION, WESTERN NORTH PACIFIC, EARLY SUMMER

INTRODUCTION

To obtain parameter of ecosystem models mainly prey preference of the whale, we have conducted whale prey species survey as a part of JARPN II 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 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. The Expert Panel also recommended accumulating quantitative ecosystem information in the subtropical, transition, and subarctic regions, to construct separate ecosystem models including whales in each region, although JARPN II modeling group built several ecosystem modes to cover the whole part of sub-areas 7, 8, and 9 (Kawahara 2009, Mori *et al*. 2009). Based on these comments, we newly started 'whale prey species survey' from 2010 or 2011 by following approach.

1. Whale prey species and whale sampling surveys conduct on the same track lines at the same period to obtain the data on prey abundance in environment and stomach contents of the whale simultaneously. This approach is useful to obtain the data on functional response of the whale.
2. Whale prey species survey vessel conducts whale sighting survey and various observation of physical and biological conditions to obtain major ecosystem information including whales in various regions and months (see Materials and Methods).

These surveys are unique in the western North Pacific and characterized that the major parameters of ecosystem models could be obtained simultaneously and also quantitatively.

Sei whales *Balaenoptera borealis* are the abundant baleen whale in the western North Pacific and migrate into high latitudinal area mainly between 40 and 47˚N during spring and summer from the low latitudinal wintering area (Fujise *et al*. 2004, Kasamatsu *et al*. 2009). Previous studies have indicated that this whale species frequently feed on small epipelagic fish species such as Japanese sardine *Saldinops melanostictus*, Japanese anchovy *Engraulis japonica*, and/or Pacific saury *Cololabis saira* in summer, suggesting the competition between whale and fisheries (Nemoto 1962, Kawamura 1973, 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 this whale species in relation to oceanographic conditions and ecosystem information are still limited (Watanabe *et al*. 2012). Such information is essential to estimate its feeding impact on commercially important small epipelagic fish species and also to obtain parameters of ecosystem models like functional response and prey preference of the whale.

In this document, we firstly report the distribution pattern of sei whale in relation to ecosystem information in a part of sub-areas 8 and 9. During cooperative survey period of whale prey species and whale sampling in this year, a total of 14 individuals of sei whale was captured. Using stomach contents data of these individuals and environmental data where these individuals were captured, functional response and prey preference of the whale will be analyzed in the future.

MATERIALS AND METHODS

Surveys were conducted in the western North Pacific enclosed by latitude from 37˚N to 43º30'N and longitude from 156ºE and 159ºE from 16 to 23 June 2011 by the trawler–type research vessel, *Hokko Maru* (1,246 GT, Hokkaido

National Research Institute of Fisheries Science, Figure 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 12 hours. All surveys were conducted during the daylight period from one hour after sunrise to one hour before sunset. Distribution and abundance of the whale prey species were investigated with midwater trawl, Matsuda–Oozeki–Hu–Trawl (MOHT, Oozeki *et al*. 2004), North Pacific Standard (NORPAC) nets, and quantitative echosounder on the track lines as follows.

Whale sighting survey

Whale sighting survey was conducted 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. However, abeam closing survey was also conducted within two nautical miles perpendicular to track line in case that the species of large cetaceans could not identified by passing mode. During the survey, two primary observers were allocated to the upper bridge.

Environmental survey

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. We also conducted chlorophyll (ACL-208DK, JFE advance) and under water irradiance (Micropro, Salantic) surveys 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 and vertical distribution of illumination, respectively, in this study area. The latter data will be analysed in relation to vertical distribution and/or migration of deep scattering layer (DSL) to estimate species composition of each DSL, because underwater irradiance is an important parameter for discriminating among organisms especially during their diel vertical migration periods (Matsuura *et al*, 2012).

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 distribution 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. 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.

The biomass of Pacific saury, which was one of the prey species of the sei whale, was estimated from midwater trawl sampling data because they are generally distributed in the sea surface layer and are difficult to detect with the echosounder. We assumed that the distribution depth of this species is 0–10 m, area of mouth opening for the trawl net is 600 m^2, and the catching efficiency of the trawl we used is 14.4 %, based on the similar sized trawl data (Ueno *et al*. 2004). To estimate water volume filtered in each sampling, average towing speed of midwater trawl in each sampling were adopted.

MOHT sampling

MOHT was towed to examine species and size compositions and vertical distribution patterns of macro–zooplanktons, especially euphausiids. 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 20 to 40 minutes. 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, 120, and 200 kHz. Samples were preserved in 5 % formalin–buffered seawater for later analysis in the laboratory.

NORPAC net sampling

We conducted NORPAC net samplings in the 0–150 m layer once a day to collect data for species and size compositions of meso–zooplanktons, especially copepods, in the epipelagic zone. The mouth opening of this net was 0.15 m^2 and the mesh size of the net was 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 by steaming at 10 knots on the track lines. Calibrations were carried out in the coastal region off eastern Hokkaido (42˚53'N, 144˚10'E) on 26 to 27 June using a standard sphere technique. A tungsten carbide sphere (38.1 mm in diameter) was used as the standard sphere. Acoustic data was analyzed by SonarData Echoview (Sonar Data Co., Ltd.) software. To estimate distribution density of Japanese anchovy and zooplankton (euphausiid and copepod) preys, we adopted information of target strength reported by Amakasu *et al*. (2010) and Fukuda *et al*. (unpubl. data, see below), respectively.

Estimate of target strength of zooplanktons

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 essential to obtain theoretical values of target strength of these species, which are important to estimate abundance of these preys by acoustic data. To calculate target strength of these animals, the Distorted-Wave Born Approximation based deformed-cylinder model (DWBA model) was adopted and dorsal-aspect target strengths as a function of the incident angle of the ensonified wave (TS-pattern) were calculated. TS-pattern of euphausiid was averaged by Foote's method (Foote 1980) using the results of the swimming angle measurements by Miyashita *et al*. (1996). TS-pattern of copepod was averaged for all swimming angles.

RESULTS AND DISCUSSION

Summary of some survey

A total of six midwater trawl surveys, six MOHT surveys, two MOCNESS surveys, and eight NORPAC, chlorophyll, and under water irradiance surveys were conducted (Tables 1 to 4). Sound speed contrast of copepods *Neocalanus* spp. and euphausiids mainly *E. pacifica* was measured for three and one times, respectively. Density contrast of copepods and euphausiids was measured 30 and 14 times, respectively. The average sound speed and density contrast values used for the model computation were 1.016 and 1.003 (copepods), 1.014 and 1.054 (euphausiid), respectively.

Distribution of sei whale relate to oceanographic condition and biological production

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. Sub-arctic boundary is defined by 34.0 PSU salinity front in the epipelagic zone (Favorite *et al*. 1976). According to our CTD data, water temperature at 100 m was higher than 5˚C in all area and 34.0 PSU salinity front in the epipelagic zone was found in the area between 39˚30' and 40˚N, indicating that this study area was located in the transitional domain north of ca. 40˚N and the transition zone to the south (Figure 2a, b).

A total of 592 nautical miles was searched. A total of 28 animals of 22 schools of large cetacean species was found by primary sighting (Table 5). Of these, sei whale was the most abundant in this study area (Table 5). This whale species was found mainly in the transition zone between 38˚10' and 39˚40'N south of the subarctic boundary in late June (Figure 2). During late July and early August, sei whale was reported to be densely distributed in the transitional domain around 44˚N in the western North Pacific enclosed by longitude from 163ºE and 166ºE (Watanabe *et al*. 2011). According to Fujise *et al*. (2004) and Konishi *et al*. (2009), sei whale was mainly captured in the transition zone south of 40˚N in May and June and in the transitional domain between 40˚ and 45˚N from July to September. These data probably indicate that sei whale migrate into the transitional domain from the transition zone in July just after our study period.

The present result also indicated that the most of sei whale was found in the area where density of chlorophyll *a* at sea surface rapidly increased from 0.6 to 0.9 mg m^{-3} (Figure 2c), which was probably corresponded to the surface convergence, where cool surface waters from the north containing high levels of chlorophyll *a* sink beneath warm and oligotrophic waters to the south (Polovina *et al*. 2001). Because distribution of surface chlorophyll density could be observed from satellite, satellite data would be useful to estimate distribution of sei whale in early summer. This chlorophyll front area was well corresponded to the distribution area of subtropical copepod species, euphausiids, and Japanese anchovy (Figure 2e, f, g). In this area, high primary production probably led increase of subtropical copepod abundance. Planktivorous Japanese anchovy may therefore migrate into and/or stay in this area from the southern oligotrophic waters, and sei whale, which is predator of euphausiids and Japanese anchovy, also seemed to migrate into and/or stay in this area for feeding. The mechanisms of high concentration of sei whales in this area could be explained by these processes, suggesting that distribution of sei whale was closely related to the biological productivity and directly related to the distribution of Japanese anchovy (see below).

Distribution of sei whale relate to prey environment

Among prey species, copepods *Neocalanus* spp. (most of which were *N. cristatus* and *N. plumchrus*), euphausiids, Pacific saury, Common squid *Todarodes pacificus*, Pink salmon *Oncorhynchus gorbuscha*, Chum salmon *O. nerka*, and Pacific pomfret *Brama Japonica* were mainly distributed in the northernmost region of the transition zone and/or in the transitional domain north of the main habitat of sei whale (Figure 2d, h-l). Contrasting with these species, euphausiids and Japanese anchovy were abundantly distributed in the main distribution area of sei whale, although euphausiids were also abundant in the southern and northern parts of transitional domain (Figure 2f, g). These data suggest that the distributions of euphausiids and Japanese anchovy greatly affect the distributions of sei whale. However, no euphausiids were found in the stomachs of sei whale and this whale species mainly fed on Japanese anchovy in their main habitat (Tamura *et al*. unpubl. data). These results might indicate that sei whale preferred Japanese anchovy prey and this prey species affect the distribution of the whale more significantly than euphausiid prey in early summer in a part of sub-areas 8 and 9.

According to Watanabe *et al*. (2011), sei whale was also mainly distributed in the distribution centre of Japanese anchovy where was located in the transitional domain and preferred Japanese anchovy prey in late July in the western North Pacific. Because Japanese anchovy undertake northward migration from the transition zone to the transitional domain during summer (Pearcy *et al*. 1996, Ichii *et al*. 2004), sei whale possibly migrate to the northward following northward migration of Japanese anchovy and continued to depend on Japanese anchovy prey from early to mid

summer. In the future, data on the relationship between distribution density of sei whale and prey preference of the whale should be accumulated in each month in the more wide area of the western North Pacific to examine this hypothesis, which is essential to estimate role of sei whales as predator.

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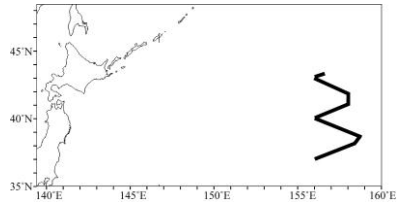

Figure 1. Research track line of whale sighting and prey species surveys in late June 2011.

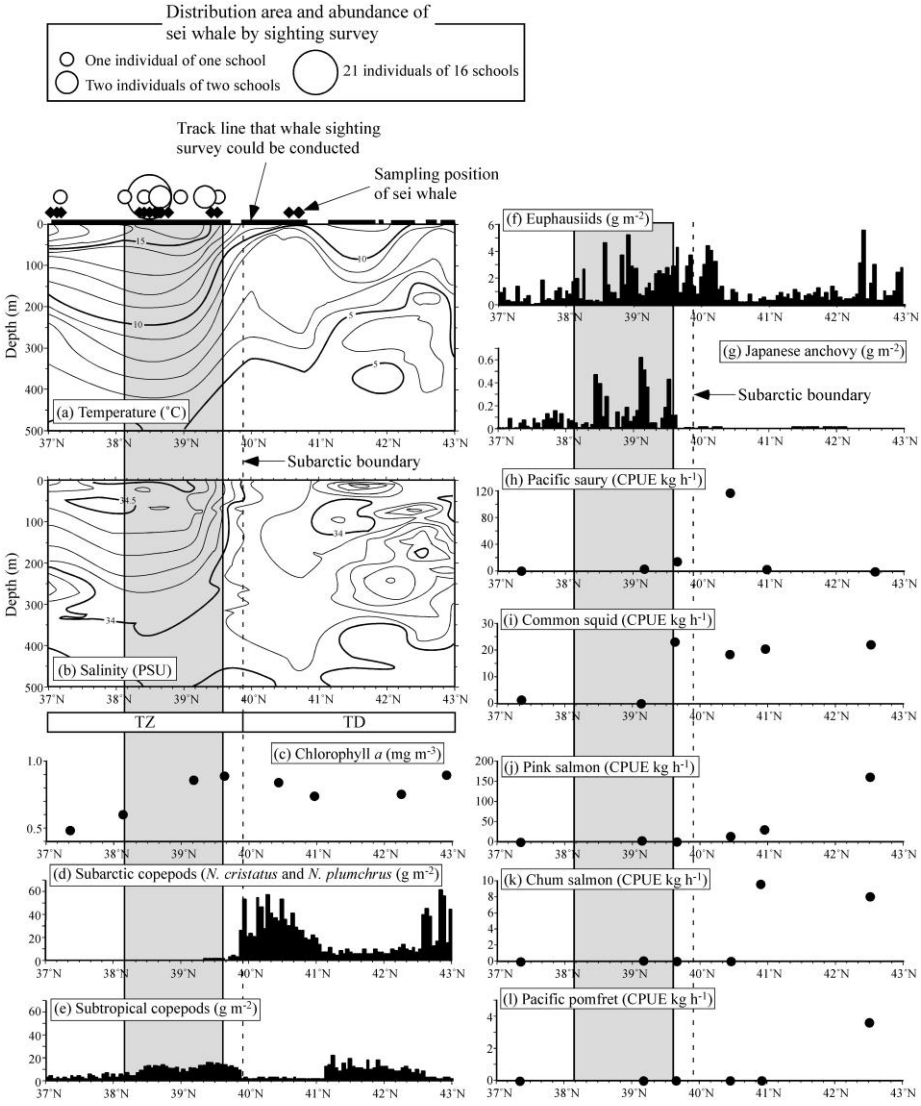

Figure 2. Sighting positions of sei whales, vertical temperature and salinity profiles, and geographical distribution of biological productivity and each fish and squid species including whale prey species along track lines in early summer (late June) 2011. Shaded area indicates main distribution area of sei whale. Sampling position of sei whale was also depicted (Tamura unpubl. data). TZ: transition zone. TD: transitional domain.

Table 1. Sampling data of midwater trawl survey.

Stn	Year	Month	Day	SST (˚C)	Latitude (N) Degree	Latitude (N) Minute	Longitude (E) Degree	Longitude (E) Minute	Sampling depth (m) Shallowest	Sampling depth (m) Deepest	Sampling duration (min)
2	2011	6	16	17.3	37	20.4	156	40.4	0	30	60
4	2011	6	17	16.7	38	30.9	158	37.0	0	30	60
7	2011	6	19	13.4	39	36.8	156	47.5	0	30	60
8	2011	6	20	11.8	40	28.6	156	57.3	0	30	60
10	2011	6	21	10.3	40	59.4	157	58.5	0	30	60
12	2011	6	22	11.0	42	33.2	156	54.2	0	30	60

Table 2. Sampling data of MOHT survey.

Stn	Year	Month	Day	SST (˚C)	Latitude (N) Degree	Latitude (N) Minute	Longitude (E) Degree	Longitude (E) Minute	Target depth (m)	Sampling duration at the target depth (min)
3	2011	6	17	16.0	38	16.8	158	24.8	150	20
4	2011	6	17	16.7	38	28.1	158	33.2	120	40
7	2011	6	19	12.4	39	39.4	156	41.7	175	20
9	2011	6	20	10.5	40	50.2	157	39.9	20	20
10	2011	6	21	10.2	41	0.7	158	7.9	110	20
13	2011	6	23	11.6	42	39.3	156	41.6	170	25

Table 3. Sampling data of MOCNESS survey.

Stn	Year	Month	Day	SST (˚C)	Latitude (N) Degree	Latitude (N) Minute	Longitude (E) Degree	Longitude (E) Minute	Sampling depth (m) Shallowest	Sampling depth (m) Deepest
11	2011	6	22	10.5	42	17.1	157	26.6	0	30
									30	50
									50	105
									105	140
									140	210
									210	255
									255	400
									400	500
14	2011	6	23	11.8	42	56.5	156	6.9	0	15
									15	35
									35	60
									60	180
									180	210
									210	320
									320	420
									420	500

Table 4. Research data that NORPAC net, chlorophyll, and under water irradiance surveys were conducted.

				SST	Latitude (N)		Longitude (E)	
Stn	Year	Month	Day	(˚C)	Degree	Minute	Degree	Minute
2	2011	6	16	17.3	37	20.4	156	40.4
3	2011	6	17	16.0	38	16.8	158	24.8
5	2011	6	18	16.7	39	10.8	157	40.0
7	2011	6	19	12.4	39	39.4	156	41.7
8	2011	6	20	11.8	40	28.6	156	57.3
10	2011	6	21	10.3	40	59.4	157	58.5
11	2011	6	22	10.5	42	17.1	157	26.6
14	2011	6	23	11.8	42	56.5	156	6.9

Table 5. Results of sighting survey for large cetacean species.

	Primary sighting		Secondly sighting	
Species	Schools	Animals	Schools	Animals
Sei whale	19	24	2	3
Sperm whale	3	4		