SC/59/O7

Cruise report of the second phase of the Japanese Whale Research Program under Special Permit in the Western North Pacific (JARPN II) in 2006 - Coastal component off Kushiro.

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ABSTRACT

The fourth survey of the JARPN II coastal component was conducted from 11 September to 31 October 2006, off Kushiro, Hokkaido, northeastern Japan (northern part of the sub-area 7), using four small-type whaling catcher boats, one echo sounder-trawl survey vessel, and one dedicated sighting survey vessel. Sampling of common minke whales was conducted in coastal waters within 50 nautical miles from the Kushiro port, and all the animals collected were landed at the JARPN II research station for biological examination. During the survey, a total of 10399.5 nautical miles (958.0 hours) was surveyed for whale sampling. Eighty four schools (85 individuals) of common minke whales were detected with a sei whale sighting (1 animal), and 35 common minke whales were collected. Average body length of the animals collected was 6.60m (SD=1.02, Range=4.61-8.12m, *n*=25) for males and 6.05m (SD=1.31, Range=4.62-8.33m, *n*=10) for females. In males, 13 animals were sexually mature, but only 2 females had attained sexual maturity. One mature female was pregnant. Composition of sex and sexual maturity recorded in the present survey was almost same as that in the previous surveys off Kushiro. Japanese anchovy (*Engraulis japonicus*) was only one dominant prey species found from whale forestomach and was detected throughout the survey period. Other 4 species, Pacific saury (*Cololabis saira*), walleye pollock (*Theragra chalcogramma*), Japanese common squid (*Todarodes pacificus*), and krill (*Euphausia pacifica*) were also detected from the stomach, but their frequency of occurrence was low. These results were different from those in the previous surveys, which indicates that prey species of common minke whales changes year by year. In the present season, migration of common minke whales into the coastal waters off Kushiro was thought to be low. Furthermore, the prey species survey suggested that the prey environment for the common minke whale off Kushiro was poor. These results are thought to be the result of unusually high sea surface temperature off Kushiro during the present survey.

KEYWORDS: COMMON MINKE WHALE; NORTH PACIFIC; COASTAL WATERS OF JAPAN; FOOD/PREY; ECOSYSTEM; SCIENTIFIC PERMITS.

BACKGROUND

After the two-year feasibility study conducted in 2000 and 2001, the full-scale survey of the second phase of the Japanese Whale Research Program under Special Permit in the Western North Pacific (JARPN II) began in 2002. The objectives of the program are, i) feeding ecology and ecosystem studies, involving prey consumption by cetaceans, prey preferences of cetaceans and ecosystem modeling, ii) monitoring environmental pollutants in cetaceans and the marine ecosystem, and iii) elucidation of stock structure of whales (Government of Japan, 2002a).

The JARPN (1994-1999) and the JARPN II feasibility study (2000-2001) revealed that common minke whales are widely distributed from offshore waters into coastal waters and feed on various prey species such as Japanese anchovy, Pacific saury, and walleye pollock (Government of Japan 2002b; Tamura and Fujise 2002). The coastal waters of Japan are very important fishing grounds. Thus, it was thought that the coastal waters are also a very important area for the full-scale JARPN II program. However, the *Nisshin Maru* research vessels can not be operated in the near shore areas, because of their movement restrictions in shallow waters and the presence of fishing gear and many boats. Furthermore, the research vessels are not available from late autumn to early spring. In order to cover the temporal and spatial gap of these vessels, in the full-scale JARPN II, sampling of common minke whales in coastal waters using small-type whaling catcher boats was planned (Government of Japan, 2002a).

Feasibility studies were carried out in coastal waters off Kushiro in autumn 2002 and off Sanriku in spring 2003, using small-type whaling catcher boats, in order to examine the logistic aspects of the methodology (Kishiro *et al.* 2003, Yoshida *et al.* 2004). From these surveys, it was concluded that no substantial problem occurred and that the coastal survey could be continued as the component of the JARPN II, using the same vessels and methodology (Government of Japan 2004b, Kato *et al*. 2004).

From results of the feasibility studies, the coastal component was revised to be conducted twice a year and to collect 60 common minke whales in each of spring and autumn (Government of Japan 2004a). The first revised survey was carried out off Kushiro in autumn 2004 and the second one followed it in autumn 2005 (Kishiro *et al*. 2005, 2006). This paper presents results of the fourth survey conducted off Kushiro, from 11 September to 31 October. The survey was authorized by the Government of Japan in compliance with Article VIII of the International Convention for the Regulation of Whaling. At the request of the Institute of Cetacean Research (ICR), the National Research Institute of Far Seas Fisheries (NRIFSF), of the Fisheries Research Agency, took the lead in the planning and conduct of the survey.

MATERIALS AND METHODS

Response to the discussion at the IWC/SC meeting

The revised JARPN II research plan was presented at the 56th IWC/SC annual meeting (Government of Japan 2004a). Revised surveys were conducted in 2004 and 2005 off Kushiro and results were reported at the IWC/SC meetings (Kishiro *et al*. 2005, 2006). Because no substantive comments or recommendations to the plan were made at these meetings, the present survey was conducted under the original revised plan (Government of Japan 2004a).

Research area

Research area was set in the same waters where the previous JARPN II coastal surveys off Kushiro were conducted (Kishiro *et al.* 2003, 2005, 2006): the research area was in coastal waters within 50 nautical miles (mostly within 30 n. miles) from the Kushiro port, southeastern Hokkaido (Fig. 1). This area is included in the northern part of the sub-area 7 established by the IWC.

Research vessels and station

Whale sampling survey

Four small-type whaling catcher boats were used as sampling vessels: *Taisho Maru* No. 28 (hereinafter referred as 28T; 47.3GT), *Koei Maru* No. 75 (75K; 46.0GT), *Katsu Maru* No.7 (7K; 32.0GT), and *Sumitomo Maru* No.31 (31S; 32.0GT). The whale sampling survey was conducted in a period from 11 September to 31 October, 2006. All the common minke whales collected were landed at the JARPN II research station established in the Kushiro port, for biological examination.

Prey species survey

The *Kaiko Maru* (KK1, 860.3GT), a trawler-type research vessel, conducted the prey species survey using a quantitative echosounder (SIMRAD ER500), mid-water trawl, and the IKMT, in a wider research area set off southeastern Hokkaido in the period from 11 to 29 September. The *Kaiko maru* also carried out oceanographic observations using a CTD. Furthermore, a sighting survey was tried as a feasibility study, in which it was examined whether sighting information could be obtained on the vessel conducting the acoustic prey species survey. Details of the prey species survey and the sighting survey are shown in Appendix 1 and 3, respectively. Oceanographic conditions revealed from the CTD observations are noted in Appendix 2.

Dedicated sighting survey

The *Kyoshin Maru* No.2 (KS2; 372.0GT) carried out the dedicated sighting survey. The survey was conducted from 2 to 27 September, following zigzag track lines predetermined in research area set off southeastern Hokkaido. The details of the survey are shown in Appendix 3. Furthermore, relation between sighting positions of common minke whales and the sea surface temperature is discussed in Appendix 4.

Sighting and sampling methods

Sighting and sampling methods were almost the same as those used in the coastal survey conducted off Kushiro in 2002 (Kishiro *et al*. 2003). The research head office in the research station controlled the sampling vessels during the survey. In order to avoid concentration of searching effort, the office determined the searching areas and routes of sampling vessels each day, from weather conditions, whale distribution, and information on coastal fisheries. Searching activity was carried out during the daytime and the vessels returned to the port every night. A researcher was on board each of the four sampling vessels, and recorded sighting and sampling information, e.g., coordinates and time of common minke whale sightings and sampling made, weather conditions, and vessel activity. Sighting information was also recorded for other baleen whales and the sperm whale. Searching was conducted by crews and researchers from the top barrel and upper bridge of vessels running at about 11 knots. All common minke whales sighted were targeted for sampling, except cow-calf pairs. When a school consisted of more than 1 animal, an individual was selected randomly from the school and then caught. Once a vessel collected a whale, it returned to the Kushiro port as soon as possible, to transport the animal to the research station. While returning to the port, even if other common minke whales were sighted, the vessel did not catch these animals. At the port, animals taken were lifted from the vessel by a crane, using a wire net and then carried to the station by an 11-ton freight trailer. At that time, the animals body weight was measured with a truck scale.

Biological research for common minke whales collected

Biological examinations of animals collected were conducted at the research station. Research items of these examinations which are summarized in Table 4 were used for studies on feeding ecology, stock structure, life history and pollutants. In addition, researchers of the Obihiro University of Agriculture and Veterinary Medicine collected oocytes from 6 females for in vitro fertilization research conducted cooperatively with the ICR.

RESULTS

Searching effort made by sampling vessels

Cruise tracks made by the 4 sampling vessels (28T, 75K, 7K, and 31S) during the survey are shown in Figure 2. Cruise tracks were widely distributed in waters 30 n. miles from the Kushiro port. Searching distance and time for each vessel are given in Table 1. Here, searching distance and time are defined as distance and time recorded under searching activity conducted by crews from the top barrel of the vessels. Total searching distance and time were 10,399.5 n. miles and 958.0 hours, respectively.

Common minke whale sightings made by sampling vessels

A total of 84 schools (85 individuals) of common minke whales were sighted during the survey (Table 2). These were 79 primary sightings (80 animals/79 schools) and 5 secondary sightings (5 animals/5 schools). Of all the 84 schools sighted, only 1 school consisted of 2 individuals. Others were of solitary animals. No cow-calf pairs were detected. A sighting of a sei whale was obtained on 11 September. This was the first record of the sei whale in the coastal surveys off Kushiro. Sighting positions of common minke whales from the sampling vessels are shown in Figure 3, with 1 sei whale sighting. Although the searching area was widely distributed in the waters 30 n. miles from the Kushiro port (see, Fig. 2), sightings of minke whales occurred along 200m isobath, particularly on the continental slope in the western side of the research area. Temporal change in density index of common minke whales recorded by the sampling vessels is shown in Table 3. The largest values were recorded in the middle of September (0.18 for SPUE and 1.63 for DI). Values decreased to the late of September, increased once in the beginning of October, and decreased again toward the end of October. Similar temporal changes were recorded in the last two coastal surveys off Kushiro conducted in 2004 and 2005.

Sampling of common minke whales

Of all the 85 animals sighted, 35 common minke whales were collected for biological examination. In the sampling process, there were no struck and lost animals. Sighting positions of animals collected are shown in Figure 3.

Prey species survey and dedicated sighting survey

The prey species survey was conducted using the trawler-type research vessel (KK1). Distribution and abundance of prey species were investigated using the quantitative echosounder (SIMRAD ER500), midwater trawl, and the IKMT. Oceanographic observation was also conducted using CTD. Among the epipelagic small fishes, Japanese anchovy was the most abundant and mainly distributed in the eastern part of the survey area. However, they were rarely captured in the central and western part of the survey area, where the whale sampling survey was conducted. Furthermore, it was remarkable that catches of the Pacific saury were extremely low in the present survey. This fact was probably caused from high sea surface temperature, as discussed in Appendix 4. These results suggest that the prey environment for common minke whales was poor in the coastal waters off Kushiro. During the sighting survey conducted on the prey species survey vessel, 1 common minke whale was detected. Further information on the prey species survey and the sighting survey is provided in Appendix 1 and 3, respectively. The dedicated sighting survey was carried out using the sighting survey vessel (KS2). Thirteen common minke whales were sighted. The number of sightings recorded in the present survey was the lowest among the 4 years. This was thought to be the result of the unusually high sea surface temperature off Kushiro, as discussed in Appendix 4. Further results from the survey are shown in Appendix 3.

Sex ratio, body length and weight of animals caught

Research items of biological examination for the 35 animals caught are summarized in Table 4, with the number of data and samples obtained. The animals consisted of 25 males and 10 females. Sex ratio of males to all the animals collected was 0.71. This ratio was almost same as recorded in the past coastal surveys off Kushiro. Average body length was 6.60m (range=4.61-8.12, SD=1.02) for males and 6.05m (range=4.62-8.33, SD=1.31) for females (Table 5). Average body weight was 3.77 tons (range=1.10-6.02, SD=1.59) for males and 2.92 tons (range=1.04-7.06, SD=2.04) for females (Table 6). In males, large animals with body length of 7m or more were collected during the survey except the last period from 21 to 31 October, in which body length of two males collected was around 5.5m (Table 5). Thirteen individuals of all the 25 males possessed body length of 7m or more (52.0%), while only two of the 8 females attained the length of 7m or more (25.0%)(Fig. 4). The two large females were collected in the second period from 21 to 30 September. Sexual maturity of animals collected is shown in Table 7 and Figure 4. In males, 13 of the 25 animals were sexually mature (52.0%), and two of 10 females had attained sexual maturity (20.0%). One mature female was pregnant. Lactating females were not observed. The maturity rate of males recorded in the present survey was slightly lower than the last year’s rate (66.7%), while the rate for females (20.0%) was higher.

Prey species of common minke whale found from forestomach

Stomach contents of the 35 animals collected were examined. Following the same methods used in the JARPN II feasibility survey conducted in 2001 (Fujise, *et al*., 2002), stomach contents were weighed to the nearest 0.1 Kg, by each of four chambers. Weights were recorded both including and excluding liquid contents. A small quantity of forestomach contents was collected and frozen for laboratory analysis. Weight of forestomach contents including liquid ranged from 3.08kg to 127.04kg. The maximum weight was recorded from a male with body weight of 5.46 tons. It was equivalent to 2.3% of the male's body weight. This animal fed on Japanese anchovies.

Forestomach contents found from the 35 minke whales are listed in Table 8. No empty stomachs were observed. Dominant prey species was the Japanese anchovy (*Engraulis japonicus*)(82.9%, observed from 29 of the 35 whales). The frequency of occurrence was higher than those recorded in the previous surveys off Kushiro. In the present survey, 4 other species were also detected: Pacific saury (*Cololabis saira*), walleye pollock (*Theragra chalcogramma*), krill (*Euphausia pacifica*), and Japanese common squid (*Todarodes pacificus*). The frequency of occurrence of these species was very low. In the last survey conducted off Kushiro in 2005, the dominant prey species changed with time. Krill were dominant at first, then frequency of occurrence of Japanese anchovies increased, and later, Japanese anchovies were most dominant (Kishiro et al. 2006). However, in the present survey, such changes in the prey species frequency were not observed: Japanese anchovies were dominant throughout the survey.

By-products of the whales

After biological examination, all the animals were processed according to the International Convention for Regulation of Whaling, Article VIII. Total weight of products including meat and blubber was 65.3 tons.

DISCUSSION

The present survey was the fourth survey of the JARPN II coastal component off Kushiro. As in previous years, no practical problems occurred in conducting the survey. During the present survey, however, typhoons, low atmospheric pressure, and thick fog often disturbed the research activities. Of total 51 day survey period, sampling vessels could conduct the research only for 36 days or 70.6% of the time. This was the lowest among the 4 years.

In the present survey, the sea surface temperature (SST) was unusually high. In Appendix 4, relation between the SST and positions of common minke whales sighted by the dedicated sighting survey are discussed. Average SST at sighting positions of common minke whales in the 4 surveys was 15.5 °C, which indicates that whale distribution is related to the SST. Indeed, Figure 3 in Appendix 4 shows that most of sightings were recorded where the SST was ≤ 16 °C. In 2006, warm waters (16°C<) spread over the waters off Kushiro: frequency of areas with the SST ≤ 16 °C was only 3.6 % (Fig. 7 in Appendix 4). This frequency has been getting lower year by year since the JARPNII coastal component off Kushiro was started in 2002 and the value recorded in the present survey was lowest. In the present season, migration of common minke whales into the coastal waters off Kushiro was also thought to be low. We could recognize that the density index recorded in the surveys was obviously related to frequency of areas with the SST ≤ 16 °C. The SST in coastal waters off Kushiro is thought to affect migration of common minke whales into the area. Possibly, this relationship can be used as an index for estimation of the magnitude of whale migration into these waters, although further analysis is needed.

Furthermore, the SST is thought to affect migration of the prey species of common minke whales. The Pacific saury is known to be one of the most important prey species of common minke whales in the western North Pacific (Tamura and Fujise 2002). In autumn, the Pacific saury migrates down to eastern Hokkaido and mode of the SST at positions where the Pacific saury fisheries operated was 15 °C (Watanabe *et al*. 2006). Figure 9 in Appendix 4 indicates that most of the Pacific saury fisheries were conducted at waters with SST ≤ 18 °C. In September 2002, during which cold water spread over the area, many saury fishing boats operated in coastal waters off Kushiro. However, in 2006, no boats conducted the saury fishing off Kushiro. Appendix 1 also shows that only an individual Pacific saury was caught by the trawl sampling in the prey species survey. The information suggests that, in 2006, the amount of migrating saury into coastal waters off Kushiro was very small, probably resulting from the spreading warm waters. The prey species survey also revealed relatively low abundance of Japanese anchovies in coastal waters off Kushiro. The Japanese anchovy is also known to be the important prey species of common minke whales in the western North Pacific (Tamura and Fujise 2002). The prey species survey indicated that amount of anchovies distributed in coastal waters off Kushiro was small, while they were very abundant in east waters off Kushiro (Figure 2 in Appendix 1). These results indicate that the prey environment for common minke whales in coastal waters off Kushiro was relatively poor in 2006. It is probable that the prey-poor environment resulted from the high SST.

Composition of common minke whales collected during the present survey was similar to that in the previous surveys off Kushiro, i.e. sex ratio of males to the animals collected was high and more than half of males had attained sexual maturity. However, composition of prey species found in the stomachs was different: in the present survey, frequency of occurrence of the Japanese anchovy was highest among the 4 years. Furthermore, in the present survey, change in the prey species frequency with time was not observed, while dominant prey species changed with time in the last survey: krill were dominant at first, then frequency of occurrence of Japanese anchovies increased, and at the last part of the survey, Japanese anchovies were dominant (Kishiro *et al.* 2006). These results indicate that prey species of common minke whales changes yearly, from environmental factors, e.g., oceanographic conditions and prey species distribution. From the present survey, we could obtain valuable information on feeding habits of common minke whales in a prey-poor environment. To evaluate food consumption of common minke whales and to obtain more information on their feeding habits and migration, further information is needed.

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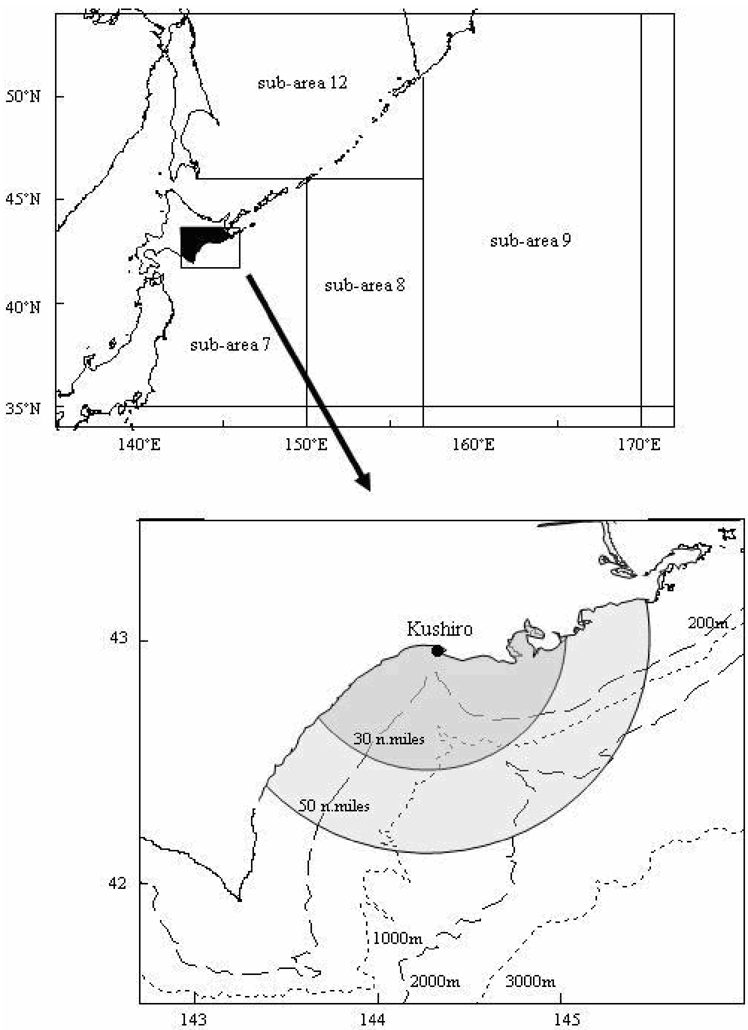

Figure 1. Research area set for the 2006 JARPN II coastal survey off Kushiro. This area is included in the northern part of the sub-area 7 established by the IWC.

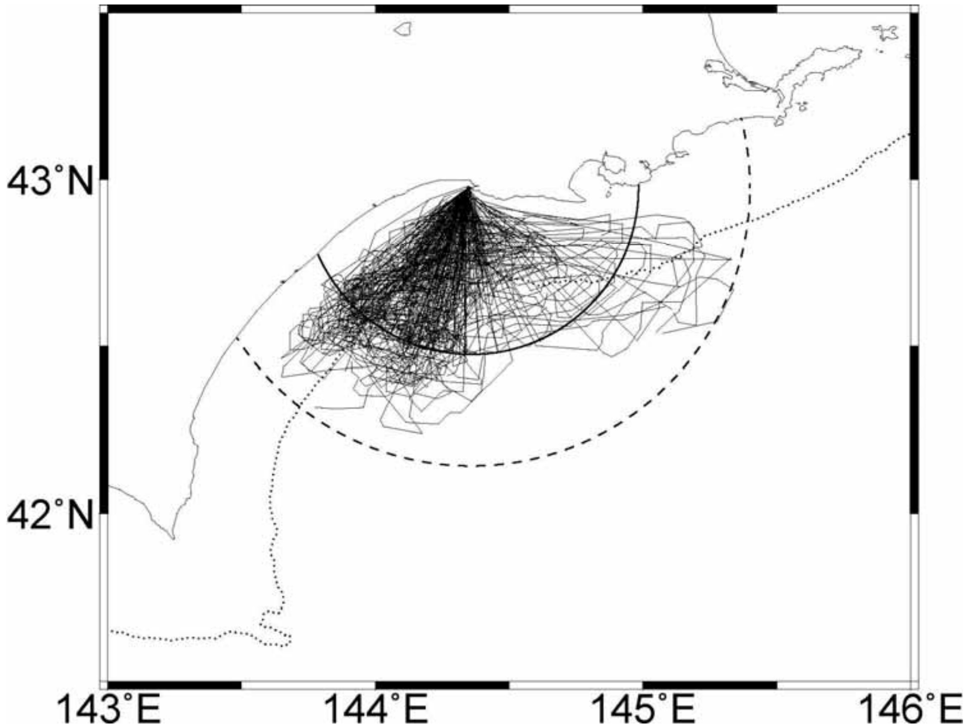

Figure 2. Cruise tracks of the sampling vessels in the 2006 JARPN II coastal survey off Kushiro, with the 200m isobath.

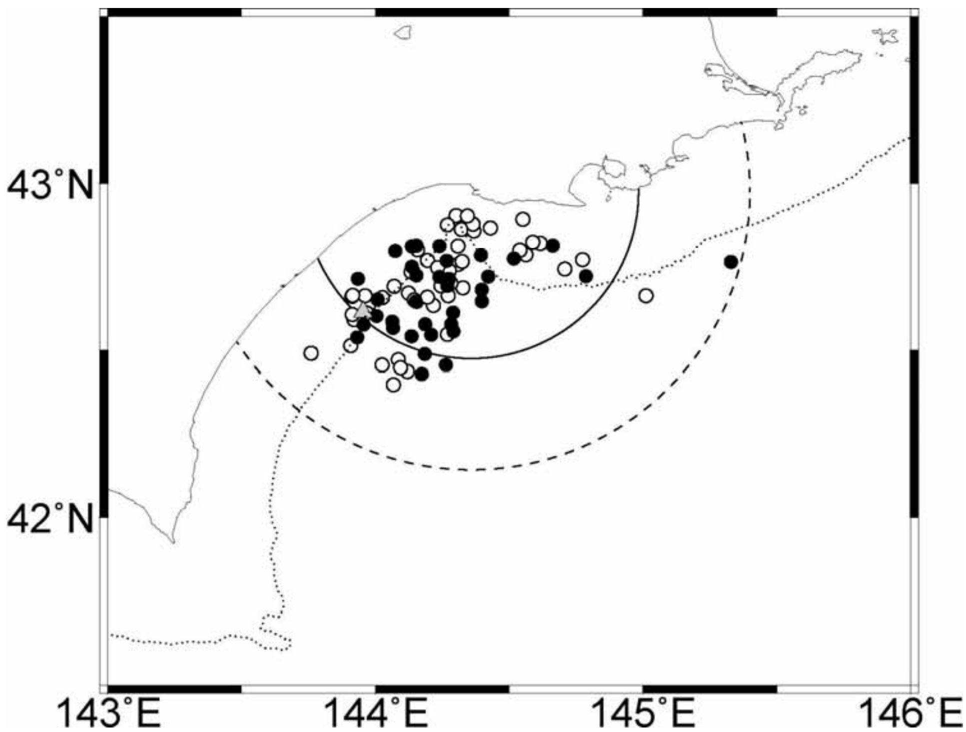

Figure 3. Sighting positions of common minke whales (circle) and a sei whale (triangle) made from the sampling vessels during the 2006 JARPN II coastal survey off Kushiro, with the 200m isobath. Closed circles are sighting positions of common minke whales collected.

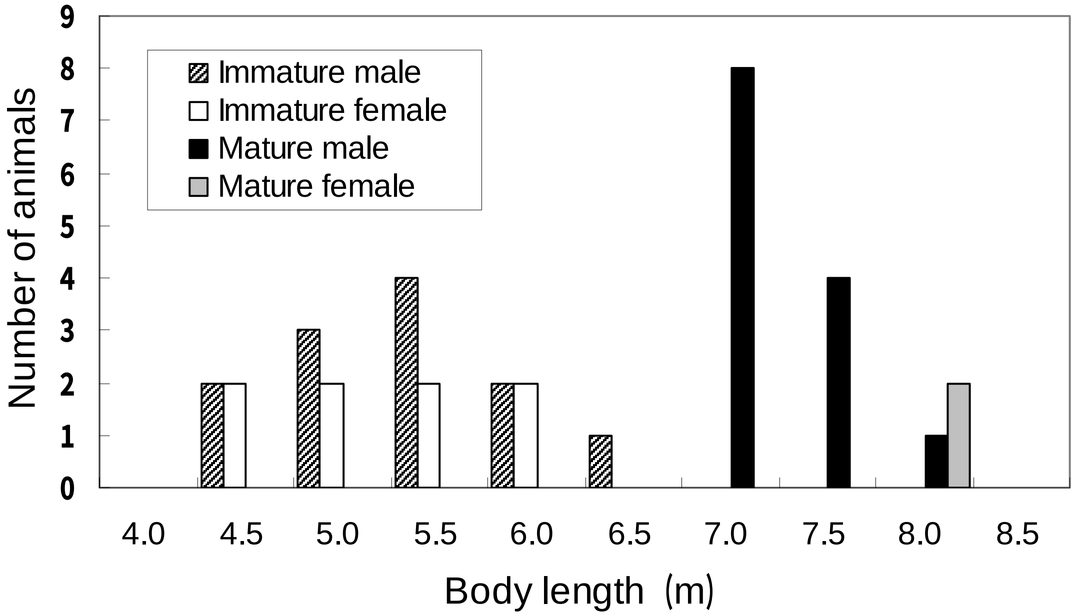

Figure 4. Body length of common minke whales collected during the 2006 JARPN II coastal survey off Kushiro.

Table 1. Searching days, hours, and distances made by the four sampling vessels in the 2006 JARPN II coastal survey off Kushiro.

Period		Sampling vessels*[1]				
		28T	75K	7K	31S	Total
11 – 20 September	Days	10	10	10	10	40
	Hours	47.7	43.0	53.3	47.8	191.8
	Distances (n. miles)	543.4	469.8	557.0	520.0	2090.2
21 – 30 September	Days	10	10	10	10	40
	Hours	52.4	45.4	50.7	46.0	194.5
	Distances (n. miles)	593.9	502.5	545.5	499.3	2141.2
1 – 10 October	Days	10	10	10	10	40
	Hours	42.9	35.9	45.7	41.3	165.8
	Distances (n. miles)	484.5	391.5	483.6	432.6	1792.2
11 – 20 October	Days	10	10	10	10	40
	Hours	44.3	46.4	50.5	44.4	185.6
	Distances (n. miles)	497.7	483.4	526.8	487.8	1995.7
21 – 31 October	Days	11	11	11	11	44
	Hours	54.1	55.4	57.2	53.6	220.3
	Distances (n. miles)	599.3	587.1	617.9	575.9	2380.2
Total	Days	51	51	51	51	204
	Hours	241.4	226.1	257.4	233.1	958.0
	Distances (n. miles)	2718.8	2434.3	2730.8	2515.6	10399.5

*[1]: 28T; *Taisho Maru* No. 28; 75K: *Koei maru* No. 75; 7K: *Katsu Maru* No. 7; 31S: *Sumitomo maru* No. 31.

Table 2. List of cetacean species and number of sightings (no. schools/no. individuals) made from four sampling vessels in the 2006 JARPN II coastal survey off Kushiro.

Period	Species	Primary*		Secondary*		Total*	
		Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
11 – 20 September	Common minke whale	34	34	3	3	37	37
	Like minke whale	8	8	1	1	9	9
	Sei whale	1	1	0	0	1	1
	Unidentified lwhale	4	4	0	0	4	4
21 – 30 September	Common minke whale	10	11	2	2	12	13
	Like minke whale	6	6	0	0	6	6
	Sei whale	0	0	0	0	0	0
	Unidentified lwhale	0	0	0	0	0	0
1 – 10 October	Common minke whale	14	14	0	0	14	14
	Like minke whale	2	2	0	0	2	2
	Sei whale	0	0	0	0	0	0
	Unidentified lwhale	4	4	0	0	4	4
11 – 20 October	Common minke whale	12	12	0	0	12	12
	Like minke whale	5	5	0	0	5	5
	Sei whale	0	0	0	0	0	0
	Unidentified lwhale	2	2	0	0	2	2
21 – 31 October	Common minke whale	9	9	0	0	9	9
	Like minke whale	2	2	0	0	2	2
	Sei whale	0	0	0	0	0	0
	Unidentified lwhale	1	1	0	0	1	1
Total	Common minke whale	79	80	5	5	84	85
	Like minke whale	23	23	1	1	24	24
	Sei whale	1	1	0	0	1	1
	Unidentified lwhale	11	11	0	0	11	11

*: The numbers probably include some duplicated sightings made by plural vessels.

Table 3. Density index of common minke whales made by sampling vessels in the 2006 JARPN II coastal survey off Kushiro.

Period	SPUE*[1]	DI*[2]
11 – 20 September	0.18	1.63
21 – 30 September	0.05	0.47
1 – 10 October	0.08	0.78
11 – 20 October	0.06	0.60
21 – 31 October	0.04	0.38
Total	0.08	0.76

*[1]: No. of primary school sightings per 1 hour searching.

*[2]; No. of primary school sightings per 100 n. miles searching.

Table 4. Summary of biological data and samples collected during the 2006 JARPN II coastal survey off Kushiro.

Samples and data	Number of animals		
	Male	Female	Total
Body length and sex	25	10	35
External body proportion	25	10	35
Photographic record and external character	25	10	35
Diatom film record	25	10	35
Body scar record	25	10	35
Measurements of blubber thickness (5 points)	22	8	30
Detailed measurements of blubber thickness (11 points)	3	2	5
Body weight	25	10	35
Body weight by parts	3	2	5
Skin tissues for DNA analysis	25	10	35
Muscle, liver, kidney, spleen, blubber, heart, and ventral groove for various analysis	25	10	35
Urine for various analysis	9	0	9
Muscle, liver, kidney, and blubber for heavy metal analysis	25	10	35
Muscle, liver, kidney, and blubber for organochlorines analysis	25	10	35
Collection of blood plasma	19	6	25
Muscle and vertebrae for lipid analysis	3	2	5
Mammary grand; lactation status, measurement and histological sample	-	10	10
Uterine horn; measurements and endometrium sample	-	10	10
Collection of ovary	-	10	10
Photographic record of foetus	0	1	1
Foetal length and weight	0	1	1
External measurement of foetus	0	1	1
Muscle, liver, kidney, heart, blubber, and skin tissues of foetus	0	1	1
Testis and epididymis; weight and histological sample	25	-	25
Stomach contents, convenient record	25	10	35
Volume and weight of stomach content in each compartment	25	10	35
Observation of marine debris in stomach	25	10	35
Stomach contents for feeding study	25	10	35
Record of external parasites	25	10	35
Earplug for age determination	25	10	35
Tympanic bulla for age determination	25	10	35
Largest baleen plate for morphologic study and age determination	25	10	35
Baleen plate measurements (length and breadth)	25	10	35
Photographic record of baleen plate series	25	10	35
Length of baleen series	25	10	35
Collection of eye lens	25	10	35
Vertebral epiphyses sample	25	10	35
Number of ribs	25	10	35
Skull measurement (length and width)	24	10	34

Table 5. Statistics of body length (m) of common minke whales collected during the 2006 JARPN II coastal survey off Kushiro.

Period	Male					Female				
	Mean	S.D.	Min.	Max.	*n*	Mean	S.D.	Min.	Max.	*n*
11 – 20 September	6.84	0.95	5.52	8.12	10	5.28	0.49	4.75	5.91	4
21 – 30 September	5.89	1.36	4.61	7.51	5	7.58	1.18	6.22	8.33	3
1 – 10 October	7.00	0.55	6.48	7.60	4	5.56	1.32	4.62	6.49	2
11 – 20 October	6.99	0.79	5.85	7.63	4	-	-	-	-	0
21 – 31 October	5.50	0.14	5.40	5.60	2	5.58	-	-	-	1
Total	6.60	1.02	4.61	8.12	25	6.05	1.31	4.62	8.33	10

Table 6. Statistics of body weight (tons) of common minke whales collected during the 2006 JARPN II coastal survey off Kushiro.

Period	Male					Female				
	Mean	S.D.	Min.	Max.	*n*	Mean	S.D.	Min.	Max.	*n*
11 – 20 September	4.17	1.60	1.84	6.02	10	1.73	0.55	1.32	2.56	4
21 – 30 September	2.91	20.3	1.10	5.38	5	5.29	2.20	2.82	7.06	3
1 – 10 October	4.21	0.85	3.54	5.36	4	2.11	1.51	1.04	3.18	2
11 – 20 October	4.28	1.33	2.54	5.70	4	-	-	-	-	0
21 – 31 October	1.99	0.01	1.98	2.00	2	2.22	-	-	-	1
Total	3.77	1.59	1.10	6.02	25	2.92	2.04	1.04	7.06	10

Table 7. Composition of sex and sexual maturity of common minke whales collected during the 2006 JARPN II coastal survey off Kushiro.

Period	Male				Female					
	Im	M	Total	Maturity(%)	Im	R	P	Total	Maturity(%)	Pregnancy(%)*
11 – 20 September	4	6	10	60.0	4	0	0	4	0.0	-
21 – 30 September	3	2	5	40.0	1	1	1	3	66.7	50.0
1 – 10 October	2	2	4	50.0	2	0	0	2	0.0	-
11 – 20 October	1	3	4	75.0	-	-	-	0	-	-
21 – 31 October	2	0	2	0.0	1	0	0	1	0.0	-
Total	12	13	25	52.0	8	1	1	10	20.0	50.0

Im: Immature; M: Mature; R: Resting; P: Pregnant.

*: Apparent pregnancy rate.

Table 8. Prey species found in forestomach of common minke whales collected during the 2006 JARPNII coastal survey off Kushiro.

Period	No. of whales	Prey species (%)					
		Japanese anchovy	Pacific saury	Walleye pollock	Krill	Common squid	Unidentified fish
11 – 20 September	14	13 (92.9)	0 (0.0)	4 (28.6)	1 (7.1)	1 (7.1)	1 (7.1)
21 – 30 September	8	6 (75.0)	0 (0.0)	1 (12.5)	0 (0.0)	0 (0.0)	2 (25.0)
1 – 10 October	6	5 (83.3)	1 (16.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
11 – 20 October	4	2 (50.0)	2 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
21 – 31 October	3	3 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Total	35	29 (82.9)	3 (8.6)	5 (14.3)	1 (2.9)	1 (2.9)	3 (8.6)

Appendix 1

2006 coastal prey species survey of JARPN II off Kushiro

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ABSTRACT

We conducted prey species survey to examine prey environment and prey preference of minke whale in cooperation with the sampling survey of the whale by small-type catcher boats off Kushiro, eastern Hokkaido, in September 2006 as a part of JARPN II study. The distribution, abundance, and size composition of the prey were investigated with the quantitative echosounder, midwater trawl, and IKMT by the research vessel Kaiko-Maru. Acoustic data were acquired by steaming at about 10.5 knots during the daytime along the track lines with operating frequency at 38 and 120 kHz. Because the acoustic data are being analyzing now, we depicted the preliminary results on distribution, abundance and size composition of prey species of minke whale mainly based on the data of predetermined trawl. Among the epipelagic small fishes, Japanese anchovy was the most abundant and mainly distributed in the eastern part of the study area where sea surface water temperature (SST) was 16-18˚C, followed by Japanese common mackerel. However, these species were rarely captured in the central and western part of the study area where SST was 18-20˚C. It was remarkable that the catches of Pacific saury, which was mainly distributed in the area where SST was lower than 15˚C, were extremely low. This fact is probably due to high SST field generally higher than 16˚C of the study area. These results suggest that prey environment of the minke whale in the 0-50 m layer was good in the eastern area and poor in the central and western area off Kushiro. Catches of Japanese common squid were extremely low, which coincides with the information of the fisheries. Walleye pollock and forked hake were caught at 120-150 m near Kushiro Canyon. Krill swarms were found at 100-150 m in the offshore region. In this year, prey species survey vessel Kaiko-Maru also conducted sighting survey of whale during prey survey period, and we confirmed that generally both surveys could be conducted concurrently by same vessel. The results of sighting survey were described in Appendix 3.

INTRODUCTION

The objective of JARPN II is to contribute to the conservation and sustainable use of marine living resources including whales in the western North Pacific, especially within Japan's EEZ (Government of Japan, 2002). The priority of this study is put on to accumulate information of prey preference and prey consumption of cetaceans to construct ecosystem models. As it is difficult to cover the coastal area especially in spring and autumn by the Nisshin-Maru, JARPN II has a new coastal component, *i.e.* the sampling survey for minke whale by small-type whaling catcher boats. In September 2006, the cooperative whale/prey surveys were conducted in the coastal region off Kushiro, eastern Hokkaido, as in 2002, 2004, and 2005. This document presents the preliminary results of the prey species survey. In addition, we had another objective in this year, that is, to examine the possibility that prey species survey and sighting survey of whale could be conducted concurrently by one vessel. This result is also presented in this document. Although a dedicated sighting vessel, Kyoshin-Maru No. 2, also conducted cooperative acoustic survey and oceanographic observations with CTD, and prey survey vessel Kaiko-Maru also conducted sighting survey concurrently with prey survey, these results are not included in this document and are described in Appendix 3.

MATERIALS AND METHODS

The prey species survey covered wide area off the eastern Hokkaido, from 143º15’E (off cape Erimo) to 146º00’E (off Nemuro), and north of 41ºN to elucidate the distribution and abundance of main prey species of minke whale (Fig. 1). In this study area, the sampling survey of minke whale was conducted in the coastal waters mainly within the 30 nautical miles (maximum 50 nautical miles) from Kushiro (Fig. 1). As many fishing gears were set near the shore, the waters shallower than 50 m were excluded in principle. The survey area was divided into coastal and offshore parts. The coastal part was further divided into east, central and west parts. Zigzag track lines were set to cover each part. The waypoints of planned track lines are shown in Table 1.

All survey was conducted in the daylight period from an hour after sunrise to an hour before sunset (generally from 06:00 to 17:00 in local time) from September 11 to 29, 2006. The distribution and abundance of the prey species were investigated with the quantitative echosounder (SIMRAD ER500), midwater trawl and Isaacs-Kidd midwater trawl (IKMT) by the stern trawler-type research vessel, Kaiko-Maru (860.25 GT) by moving at about 10.5 knots on the track lines. Acoustic data were acquired with Echoview Ver.3 (Sonar Data Co., Ltd.). Calibrations were carried out off Shiranuka near Kushiro in September 15 using the copper sphere technique. The midwater trawl net had a mouth opening of about 30 x 30 m with a 17.5 mm liner cod end. The sampling depth and the height of the mouth of the net were monitored with SIMRAD PI32 net monitor system and the small-type temperature and depth recorders (TDR). Towing speed was 3-5 knots for the trawl and 2 knots for IKMT.

A total of 20 times midwater trawl survey was conducted. Of these, samplings at predetermined stations were conducted 19 times to identify the species and size compositions of biological backscatterings detected by the echosounder, and also to examine the distribution and abundance of squids and neustonic organisms like Pacific saury that are difficult to detect with the echosounder. At each predetermined station, trawl net was towed at 0-100 m or 0-30 m. A target trawling was made near Kushiro canyon to identify the species and size compositions of backscatterings of slope water demersal fishes. All samples were identified to the lowest taxonomic level possible and wet weight of each species was measured aboard the ship. For the major species, body length of 100 individuals was measured. A part of sample was frozen at below –20˚C to measure caloric value of the main prey species. IKMT samplings were conducted two times to identify the species and size compositions of backscatterings of the krill. Samples were fixed in 10% buffered formalin seawater. A CTD cast was made down to 500 m or near the bottom where depth was less than 500 m at each sampling station to measure temperature and salinity profile in the study area. Detailed methods and data of sighing survey of whale are shown in Appendix 3 in the report.

RESULTS AND DISCUSSION

The results of trawling operations and the catches by species are shown in Table 2. The detail data of oceanographic conditions are described in Appendix 3 in the report. While the acoustic data are being analyzing now, the preliminary results on distribution, abundance and size composition of main prey species of minke whale are depicted as follows mainly based on the data of predetermined trawl.

Among the small pelagic nektons that were distributed in the 0-50 m layer, Japanese anchovy (mainly 10-13 cm in scale length) was the most abundant and mainly captured from the continental shelf to the offshore region of the eastern part of the study area (CPUE: 522 ± 738 kg / h, mean ± S.D.), where sea surface water temperature (SST) was 16-18˚C (Fig. 2). The abundance of this species seems to be several times higher than in 2005 when abundance of adult sized anchovy were very low due to recruitment failure of 2004 year class (Kawahara et al., 2005). However, this species was rarely distributed in the central and western part of the study area where SST was 18-20˚C. Juvenile Japanese common mackerel (mainly 10-14 cm in fork length, FL) was secondary abundant species and was mainly distributed in the area of 16-18˚C SST as was also shown in Japanese anchovy (4 ± 12 kg / h, Fig. 2). Japanese sardine (mainly 11-17 cm scale length) and Japanese common squid (2-12 cm in dorsal mantle length) were sometimes captured, but their CPUE at each station was less than 0.5 kg / h (Table 2). In this year, CPUE data of commercial squid fishing (Hokkaido fisheries experimental station, 2006) and bottom trawl data around continental shelf edge conducted by Hokkaido National Fisheries Research Institute (Nishimura, unpubl. data) also indicated the low abundance of the squid off eastern Hokkaido in summer and autumn.

The results of previous three years (in 2002, 2004, 2005) indicated that Pacific saury was one of the abundant epipelagic small fishes in this study area in autumn (Kawahara et al. 2003, 2004, 2005), however, catches of this species were extremely limited and only one individual (26.2 cm in knob length) was captured in this year (Fig. 2). Furthermore, the fishing grounds of Pacific saury were restricted to the east of the study area during the survey period. Considering that the SST of the habitat of Pacific saury off Kushiro was generally lower than 15˚C in September and the SST of the most part of this study area was higher than 16˚C (Fig. 2), these facts suggest that the southward migration of Pacific saury to the eastern Hokkaido was greatly delayed due to an extrusion of the higher temperature water from the south.

The result of targeting trawl at the continental shelf region of Kushiro canyon, where is located in the central part of the survey area, indicated that backscatterings between 120-150 layer was mainly composed by adult walleye pollock (mainly 37-43 cm FL), followed by forked hake *Laemonema longipes* (mainly 44-48 cm FL), which was firstly recorded in the prey species survey off Kushiro (see stn. 8 in Table 2). Krill was distributed mainly at 100-150 m from the edge of the continental shelf to the oceanic region. Year-to-year change in abundance and distribution patterns of these species will be estimated in the future.

In summary, based on the predetermined trawl survey, the prey-rich environment for minke whales was observed in the eastern region off Kushiro in terms of abundance of Japanese anchovy although other epipelagic nektons was rarely distributed in this area. In the western region off Kushiro, prey environment of the whales seemed to be poor in terms of abundance of epipelagic nektons. The prey environment of the minke whale in the 0-50 m layer seems to largely fluctuate by year, which may be closely related to the hydrographic interaction between the Oyashio and Kuroshio Currents. The acoustic and CTD data will be analyzed including data collected by Kyoshin-Maru No. 2 and a comparison with data from the whaling survey will be made to estimate the prey preference of minke whale.

We confirmed that generally acoustic survey of prey species and sighting survey of whale could be conducted concurrently by Kaiko-Maru. However, sighting effort was naturally reduced because this survey could not be conducted during the net sampling period. Furthermore, in case of Kaiko-Maru, both midwater trawl and IKMT use the same winch and warp. When we exchange the both nets, about one hour is required and during this time, we had to stop the sighting survey because this operation was needed all members of deck workers and some of them concurrently hold the position of sighting investigators. Therefore, survey planning that avoids frequent change of the both nets is needed in the further.

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Table 1. Waypoints of planned track lines

WP	Latitude	Logitude	Area
W-1	42 Þ11.0'N	143 Þ49.0'E	Coast West
W-2	41 Þ56.0'N	143 Þ20.0'E	Coast West
W-3	41 Þ41.0'N	144 Þ07.5'E	Coast West
W-4	41 Þ26.0'N	143 Þ15.0'E	Coast West
W-5	41 Þ11.9'N	143 Þ51.5'E	Coast West
W-6	41 Þ00.0'N	143 Þ24.5'E	Coast West
C-1	42 Þ38.0'N	143 Þ49.0'E	Coast Central
C-2	41 Þ56.0'N	144 Þ04.0'E	Coast Central
C-3	42 Þ55.0'N	144 Þ19.0'E	Coast Central
C-4	42 Þ00.5'N	144 Þ34.0'E	Coast Central
C-5	42 Þ54.0'N	144 Þ49.0'E	Coast Central
C-6	42 Þ21.0'N	145 Þ00.0'E	Coast Central
E-1	42 Þ25.0'N	145 Þ00.0'E	Coast East
E-2	42 Þ59.0'N	145 Þ10.0'E	Coast East
E-3	42 Þ15.0'N	145 Þ25.0'E	Coast East
E-4	43 Þ05.0'N	145 Þ40.0'E	Coast East
E-5	42 Þ42.0'N	145 Þ55.0'E	Coast East
O-1	41 Þ45.0'N	144 Þ12.0'E	Offshore
O-2	41 Þ00.0'N	144 Þ42.0'E	Offshore
O-3	42 Þ11.0'N	145 Þ12.0E	Offshore
O-4	41 Þ00.0'N	145 Þ42.0'E	Offshore
O-5	41 Þ53.0'N	146 Þ00.0'E	Offshore

Table 2. Sampling data.

A) Midwater trawl

Stn	Predetermined/ target	Area	D/N	採集日	SST	Latitude	Longitude	Depth	Sampling duration	CPUE (kg/h)								
					(ÞC)	(ÞN)	(ÞE)	(m)	(minutes)	Japanese anchovy	Japanese sardine	Common mackerel	Pacific saury	Walleye pollock	Forked hake	Other fishes	Common squid	Other squids
1	P	Coast West	D	2006.9.12	21	41-00.0	143-24.5	0-100	21	0	0	0	0	0	0	0	0	0
2	P	Coast West	D	2006.9.12	21.1	41-16.65	143-37.78	0-100	112	0.4	0	0	0	0.8	0	0.1	0.3	0
3	P	Coast West	D	2006.9.13	21.3	41-29.1	143-25.8	0-30	40	0	0	0	0	0	0	0	0	0
4	P	Coast West	D	2006.9.13	21.5	41-39.1	144-00.0	0-100	60	14.7	0	0	0	0	0	+	0	0
5	P	Coast West	D	2006.9.14	21.5	42-05.7	143-38.8	0-100	60	0	0	0	0	0	0	+	0	0
6	P	Coast Central	D	2006.9.16	21.2	42-00.7	144-02.2	0-100	60	0.2	0	0	0	0	0	+	0	+
7	P	Coast Central	D	2006.9.16	18.7	42-28.9	144-12.3	0-30	30	0	0	0	0	0	0	0	0	0
8	T	Coast Central	D	2006.9.17	18.7	42-53.4	144-18.6	0-30	50	53.4	0	0	0	0.0	0.0	0	0	0.8
								120-150	7	0	0	0	0	3120.0	238.3	0	0	0
9	P	Coast Central	D	2006.9.18	17.7	42-18.96	144-28.87	0-100	45	0	0	0	0	0	0	+	0.1	+
10	P	Offshore	D	2006.9.19	20.8	41-07.5	144-39.8	0-100	60	+	0	0	0	0	0	0	0	+
11	P	Coast East	D	2006.9.21	18.1	42-39.87	145-54.94	0-30	30	222.6	0	0	0	0	0	0	0	0
12	P	Coast East	D	2006.9.21	14.8	42-59.3	145-45.6	0-30	15	902.4	0	0	0	0	0	0	0	0
13	P	Coast East	D	2006.9.22	17	42-43.56	145-33.23	0-100	60	0	0	0	0	0	0	1.0	+	0
14	P	Coast East	D	2006.9.22	17.3	42-14.1	145-24.7	0-30	5	2332.8	0	0	0	0	0	0	0	0
15	P	Coast East	D	2006.9.23	15.2	42-38.44	145-15.43	0-30	30	145.6	0	0	0.1	0	0	0	0	0
16	P	Coast East	D	2006.9.23	14.8	42-39.3	145-04.3	0-30	30	1553.6	0.2	0	0	0	0	0	+	0
17	P	Coast East	D	2006.9.24	18	42-24.3	145-00	0-100	45	1295.6	0	47.4	0	0	0	0	0	0
18	P	Coast Central	D	2006.9.24	15.9	42-51.1	144-48.6	0-30	30	676.6	0.3	0.4	0	0	0	0	0	0
19	P	Coast Central	D	2006.9.25	18.2	42-30.2	144-42.6	0-30	30	122.0	0	0	0	0	0	0	0	0
20	P	Coast Central	D	2006.9.26	15.9	42-00.7	144-35.0	0-100	45	0	0	6.6	0	0	0	0	0	0

B) IKMT

21	P	Offshore	D	2006.9.26	17.8	42-10.3	145-08.1	60	3
								80	3
								100	9
22	T	Offshore	D	2006.9.26	17.9	42-10.0	145-10.2	170	12

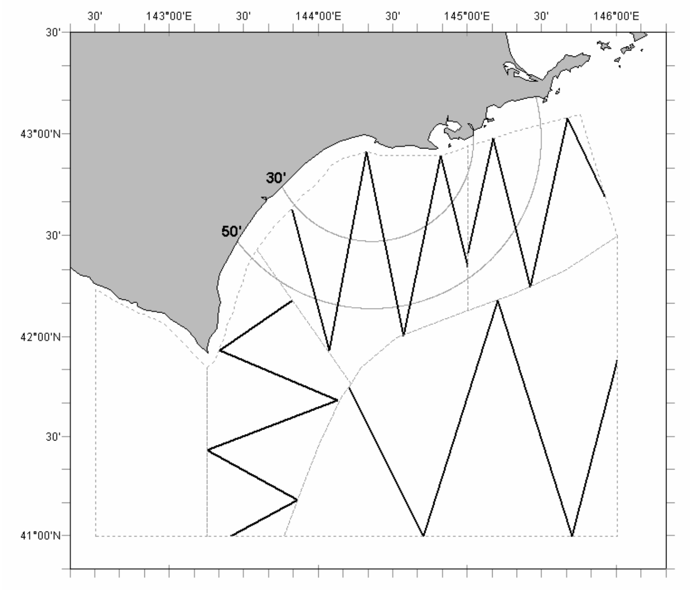

Fig. 1. Survey area and planned track lines of the prey species survey in 2006 off Kushiro. Whaling was conducted mainly within 30 (maximum 50) nautical miles from Kushiro.

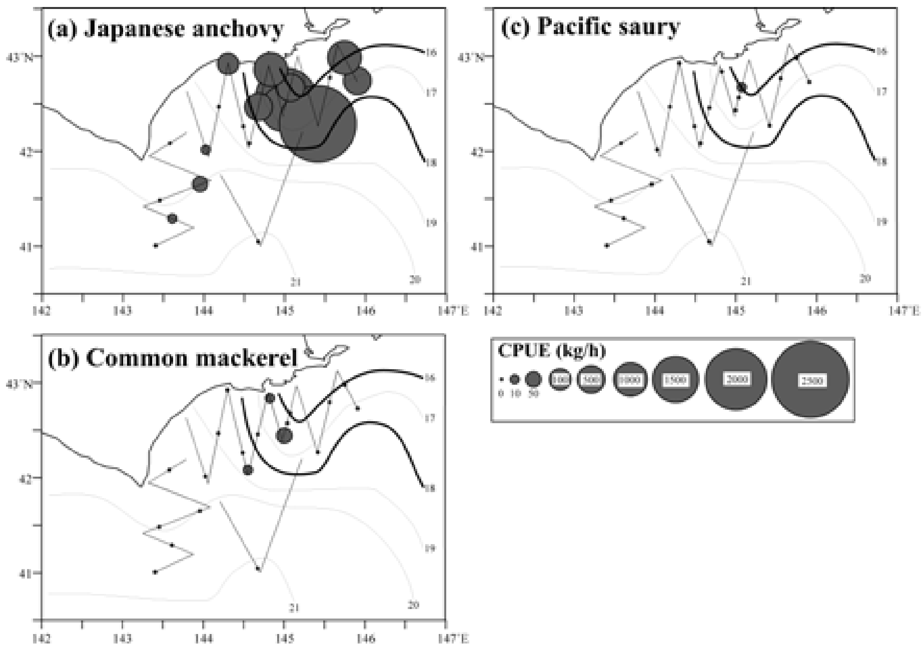

Fig. 2. Distributions of (a) Japanese anchovy, (b) Japanese common mackerel, and (c) Pacific saury based on the predetermined trawl samplings and distributions of isotherms at the sea surface off Kushiro in September 2006.

Appendix 2

Oceanographic conditions in the JARPN II research area off Kushiro, northeastern Japan, in September 2006

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ABSTRACT

A prey species survey was conducted in September 2006 using *Kaiko-Maru* as a part of coastal component of JARPN II. The survey covered a block where common minke whales were found. During the survey, oceanographic observation with CTD was made to make clear the environment of their prey. Water masses in the survey area have characteristics of the Oyashio water.

Introduction

A prey species survey was conducted in the JARPN II research area off Kushiro, northeastern Japan in September 2006, using *Kaiko-Maru* in cooperation with the whale sampling survey (Fig. 1).

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

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

Data and Methods

Hydrographic observations with a conductivity-temperature-depth profiler (CTD; SBE 19) were carried out from 12 to 26 September in the research area off Kushiro using *Kaiko-Maru*. Salinity compensation for CTD data was not done using water sampling data.

Oceanic fronts and water masses are usually detected by subsurface temperature map, because they are obscure in sea surface temperature distributions from summer to fall seasons and the Oyashio water spreads into the subsurface layer (Table 1). Axis of the Kuroshio Extension is defined by the 14°C isotherm at the depth of 200m (Kawai , 1969). The warm water spread from Kuroshio Extension is defied by temperature more than 10°C at the depth of 100 m. The first and the second Oyashio Intrusions are defined by temperature less than 5°C at the depth of 100 m (Murakami, 1994). We use these indices to know the distribution of water mass in the survey area.

The oceanographic conditions in September 2006 are detected by 100m and 200m temperature maps using the monthly mean subsurface temperature from NEAR-GOOS database.

Oceanographic conditions in the research area

The upper panel in Figure 2 shows the Temperature-Salinity diagrams in the survey area. There is no typical Kuroshio water characterized by high salinity profile around 34.5psu, but Oyashio water characterized by cold profile less than 5°C shown in Fig. 2. It is appear that water masses in the survey area have characteristics of the Oyashio with warm surface water.

Figure 3 shows temperature and salinity maps at the depth of 100 m. All area have characteristics of the cold (less than 10°C) and low salinity (over 34 psu) water, especially the middle and eastern part of this area was occupied by Oyashio water, which is colder (less than 5°C) and lower salinity (less than 33.5 psu) than the water in the western part of this area.

Figure 4 shows the vertical sections of temperature and salinity along the line shown in Figure 4. The warm water, warmer than 15°C, lied at the surface layer upper 20 m depth, and seasonal thermocline lies between 20 m and 100 m depth. Cold water was observed below the thermocline. All layers were occupied by low salinity water, less than 34 psu.

Figure 5 shows the schematic hydrographic map in September 2006. The southern limit of the 1st Oyashio Intrusion moves southward from April to November. The position of the 1st Oyashio Intrusion in September 2006 was at 41ºN on 143º30'E line, which was a slightly northward position from monthly mean location in September (40º20'N). Tsugaru warm water spread eastward to south of the Cape Erimo, and shows a front with the 1st Oyashio Intrusion. All stations in the survey area were distributed in the Oyashio water defined by 100 m temperature which is colder than 5ºC.

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Table 1. Extraction method from temperature map to determine the position of each water mass.

Target characteristics	Extraction method
Kuroshio Extension Axis	14°C isotherm at 200m
Warm-core ring	Temperature front at 200m
Oyashio front	5°C isotherm at 100m
Oyashio water	Area with T<5°C at 100m
Cold water	Area with 5°C<T<10°C at 100m
Warm water	Area with T > 10ºC at 100m and T < 14ºC at 200m

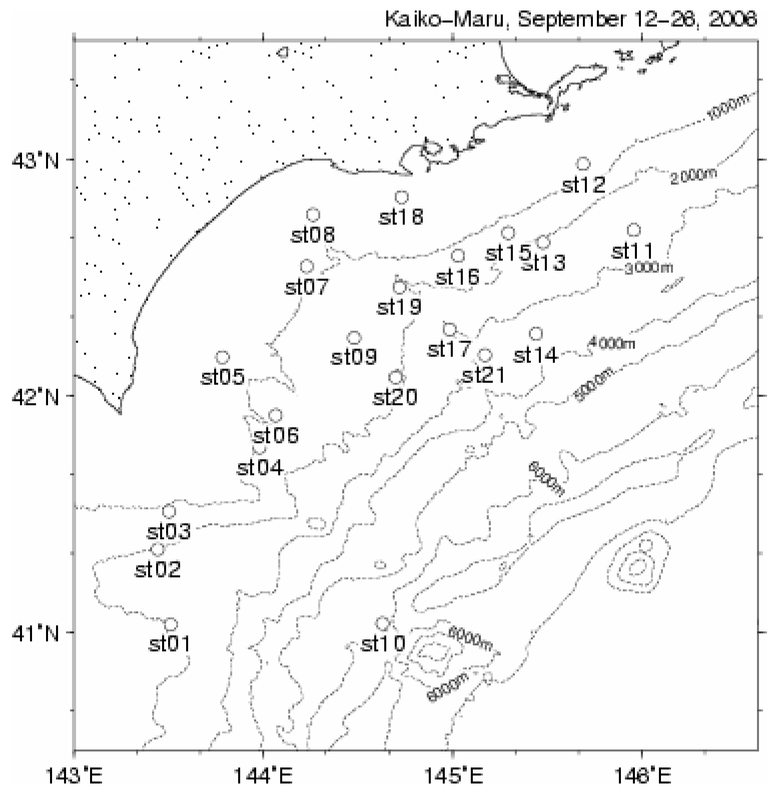

Figure 1. Station map observed by *Kaiko-Maru* in 12-26 September 2006.

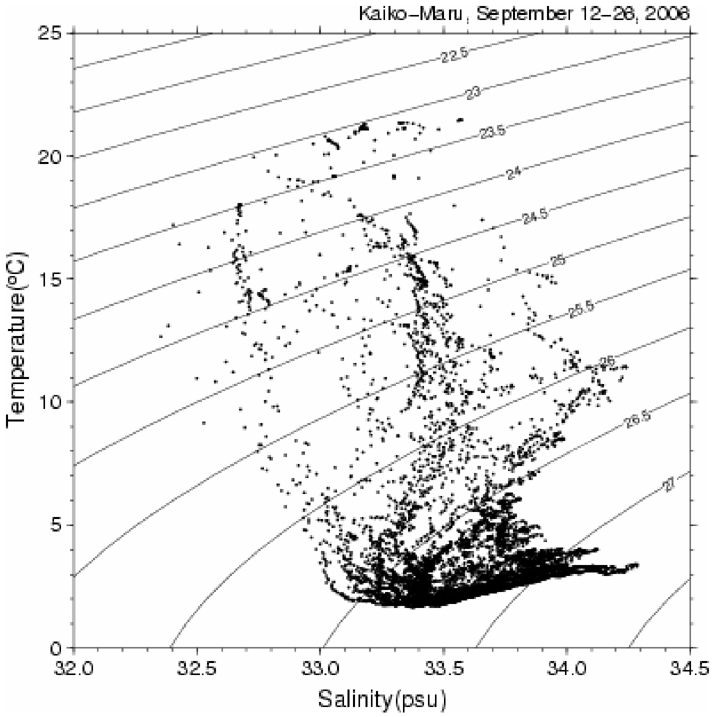

Figure 2. Temperature-Salinity diagrams using CTD station data observed by *Kaiko-Maru* in 12-26 September 2006. Each thin line in this figure denotes a density line of sigma-t.

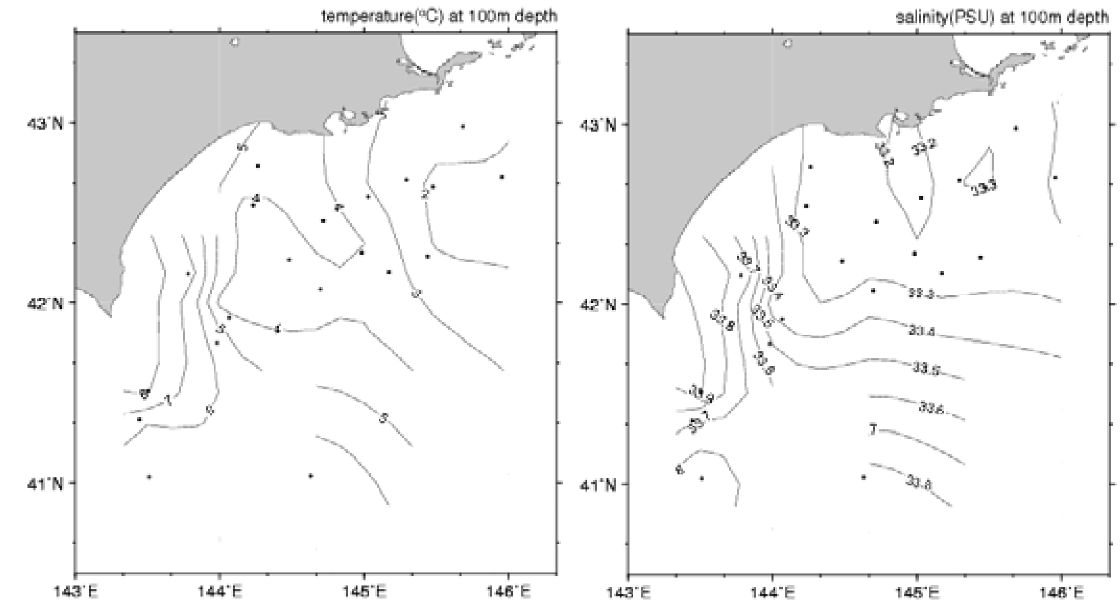

Figure 3. 100 m temperature (left panel) and salinity (right panel) maps observed by *Kaiko-Maru* in 12-26 September 2006.

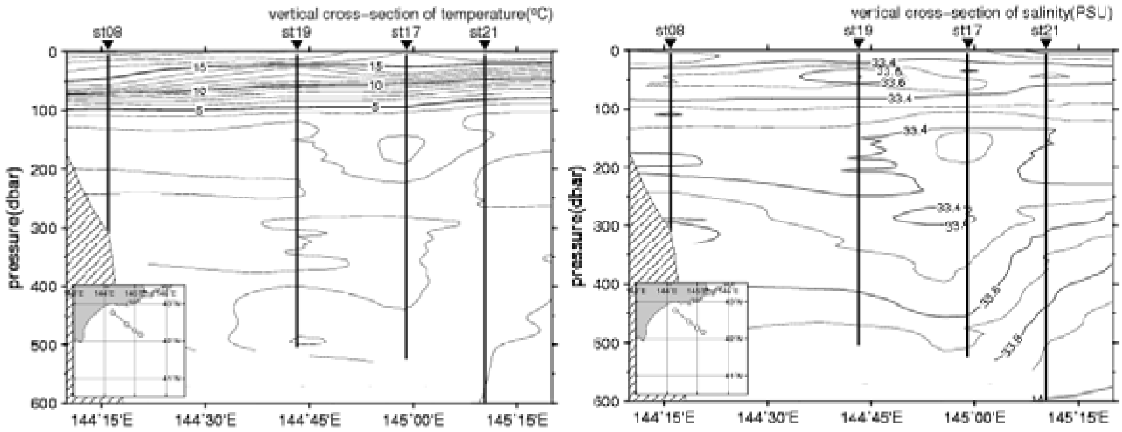

Figure 4. Vertical sections of temperature (left panel) and salinity (right panel) observed by *Kaiko-Maru* in 12-26 September 2006.

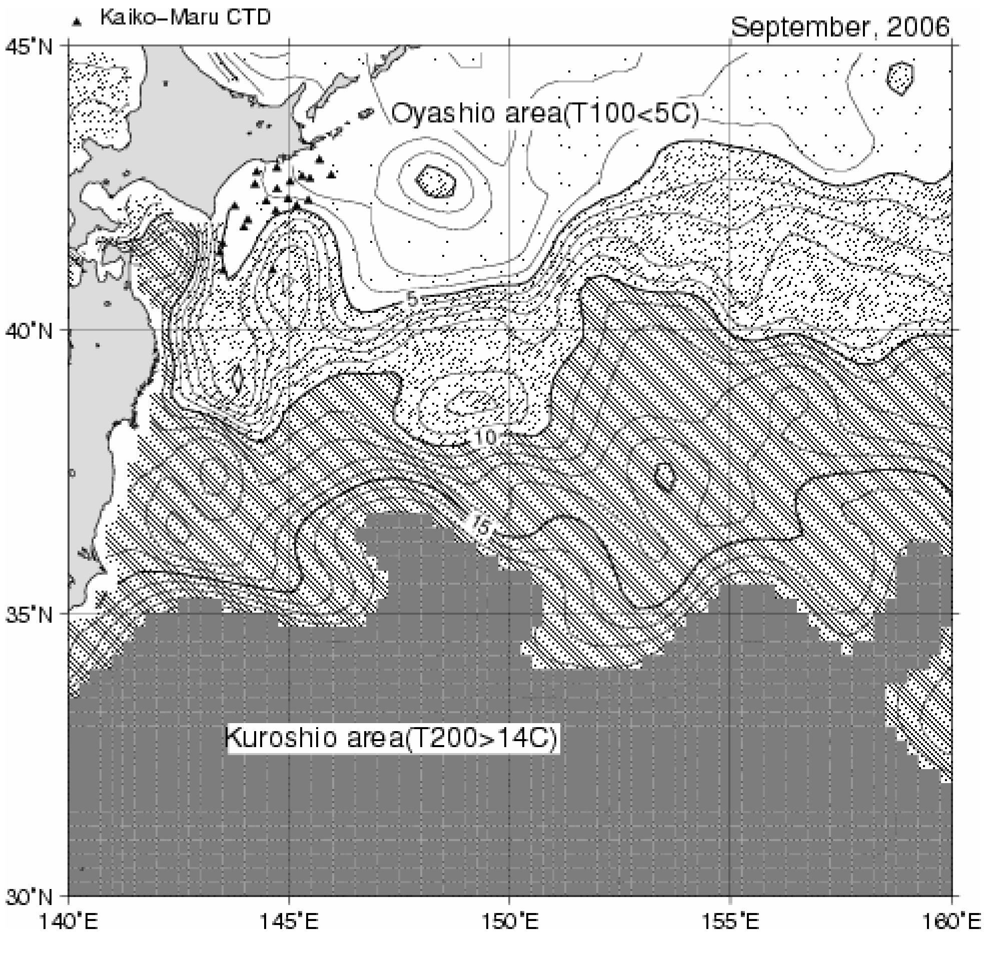

Figure 5. Schematic hydrographic map in Tohoku area, northwestern Pacific, in September 2006 with station map observed by *Kaiko-Maru*.

Appendix 3

Cruise report of the dedicated sighting survey in 2006 JARPN II coastal component off Kushiro, northeast Japan.

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ABSTRACT

A cetacean sighting survey using the line transect method was conducted concurrently with the whale sampling and the whale prey surveys off the coast of Kushiro, Hokkaido, Japan in September 2006, as a part of coastal component of 2006 JARPN II full scale study. The primary objective of the sighting survey was abundance estimation of baleen whale in the survey area. The research vessel *Kyoshin-Maru No.2 (KS2)* and *Kaiko-Maru (KK1)* were dedicated to the sighting survey. Total searching distances were 1344.3 n.miles (994.0 n.miles by KS2 and 350.3 n.miles by KK1). A total of 70 individuals of 49 schools primary sightings were made. They included 13 common minke and 31 sperm whales.

INTRODUCITON

A cetacean sighting survey using the line transect method was conducted concurrently with the whale sampling and the whale prey surveys off the coast of Kushiro, Hokkaido, Japan in September 2006 as a part of coastal component of 2006 JARPN II full scale study (Government of Japan, 2004). The primary objective of this survey was to estimate baleen whale abundance in the coastal component survey area. Preliminary results of the cetacean sighting survey are presented in this paper. Kyoshin-Maru No.2 and Kaiko-Maru also conducted quantitative echo-sounder survey, and Kaiko-Maru also prey species survey using mid-water trawl net and oceanographic observations. Results were described in Appendix 1 and 3.

MATERIALS AND METHODS

The cetacean sighting survey was conducted in small survey block “7N”, which were set within Sub-area 7 as northern part from latitude 41-00N. Near shore area of the survey block where the water depth is less than 50m, was not surveyed because many fisheries gears were set in there. The survey block was further divided into the coastal and offshore area. The coastal area also divided into four small areas. The boundary between coastal and offshore area was set on the line parallel to the coastline and the distance between the boundary and coastline was 60 n.miles. The survey was conducted from 2 to 27 September 2006. Details of itinerary were shown in Table 1. *Kyoshin-maru No.2* (KS2, 372GT) and *Kaiko-Maru* (KK1, 860.25GT) engaged in the cetacean sighting survey. Sighting survey procedures were same as offshore component of 2006 JARPN II, but the survey mode was only restricted to passing mode (NSP). Natural marking record and biopsy sampling experiments were attempted at grey, blue, humpback and right whales. These experiments were attempted at the opportunistic basis. Visual observation of large baleen whale feeding behaviour was attempted. If the behaviour was observed, it was recorded on camera.

RESULTS AND DISCUSSION

Surveyed tracklines and sighting positions of large baleen whales including common minke whales (*Balaenoptera acutorotrata*) and Sperm whales were shown on Fig 1. Total searching distances were 1344.3 n.miles (994.0 n.miles by KS2 and 350.3 n.miles by KK1). A total of 70 individuals of 49 schools primary sightings were made. They included 13 common minke and 31 sperm whales. Details of sightings were listed on Table 2. Natural marking record and biopsy sampling experiments were not made. No large baleen whale feeding behavior was observed. Relation between sighting positions of common minke whales by the dedicated sighting surveys and the sea surface temperature is discussed in Appendix 4.

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Special thanks are given to the crews for their dedication in collecting data. The authors would like to thank Dr. Hiroshi Hatanaka (The Institute of Cetacean Research).

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Table 1. Details of survey itinerary.

Date	Event
9/1	Kyoshin-Maru No.2 depart from Kushiro Port, Hokkaido, Japan
9/2	Kyoshin-Maru No.2 start sighting survey
9/11	Kaiko-Maru depart from Sendai-Shiogama Port, Miyagi, Japan
9/12	Kaiko-Maru start trawl trial survey, equipment examination
9/14	Kaiko-Maru arrive at Kushiro Port.
9/15	Kaiko-Maru depart from Kushiro Port
9/15	Both vessels were conducted calibration of quantitative echosounder
9/16	Kaiko-Maru start sighting and trawl survey
9/18	Kyoshin-Maru No.2 end sighting survey
9/20	Kyoshin-Maru No.2 arrive at Sendai-Shiogama Port
9/27	Kaiko-Maru end all survey
9/29	Kaiko-Maru arrive at Sendai-Shiogama Port, Miyagi, Japan

Table 2. Summary of cetacean sightings.

Species	Kyoshin-Maru No.2				Kaiko-Maru			
	Primary		Secondary		Primary		Secondary	
	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Common minke whale	12	12	1	1	1	1		
Bryde's whale	1	1						
Sei whale	3	4					1	1
Fin whale					1	1		
Sperm whale	10	23			8	8		
Like common minke whale	2	2	1	1	1	1		
Unidentified Large cetaceans	3	10	1	4	1	1	1	1
Unidentified cetaceans	2	2			4	4		
Total	33	54	3	6	16	16	2	2

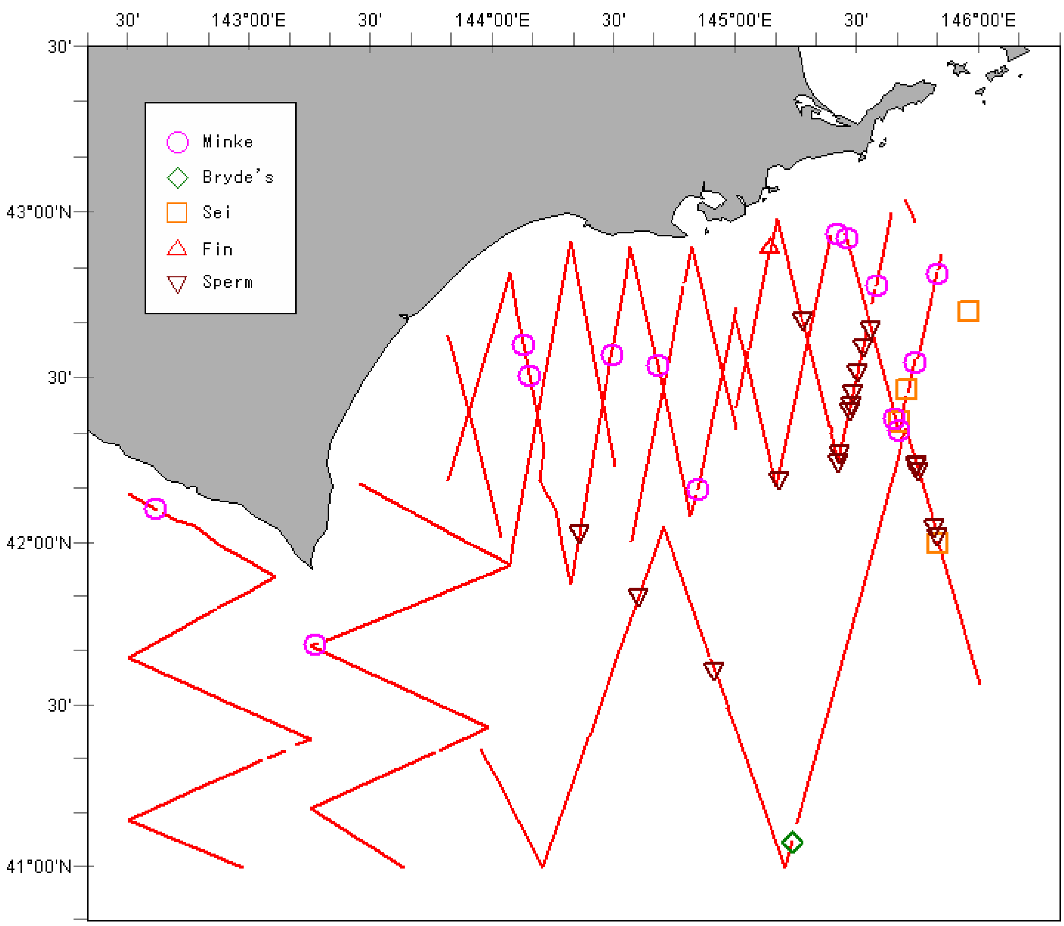

Fig 1. Sighting survey effort and sighting position of common Minke whales, Sei whales, Bryde's whales, Fin whales and Sperm whales in the 2006 JARPN II coastal survey by dedicated survey vessels "Kyoshin-Maru No.2" and "Kaiko-Maru".

Appendix 4

High sea surface temprature caused low influx of common minke whales to the Kushiro water in September 2006

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ABSTRACT

Dedicated sighting surveys of common minke whales off Kushiro were conducted in September in 2002, 2004, 2005 and 2006 as a part of coastal component of JARPNII. Satellite derived data (Aqua-MODIS) showed that SST near the Kushiro port (Block C) where the sampling of common minke whales took place remarkably high in 2006. Average SST in 2002, 2004, 2005 and 2006 in block C were 16.0, 16.3, 17.7 and 18.0 °C, respectively. Density index (DI, the number of schools per 100 n.miles) of common minke whales in block C in 2006 was lowest among the surveyed years. DIs in 2002, 2004, 2005 and 2006 in block C were 12.1, 5.0, 2.7 and 2.0, respectively. Average SST at the positions of sightings of common minke whales in block C in 4 years was 15.1. Frequencies of area of SST ≤ 16 °C in block C in 2002, 2004, 2005 and 2006 were 92.5, 80.7, 22.9 and 3.8 %, respectively. Small area of appropriate SST (≤ 16 °C) for common mike whales caused their low influx to Block C in 2006. Magnitude of influx of common minke whales to the Kushiro water due to the southbound migration would be controlled by the aerial extent of SST ≤ 16 °C. The number of commercial Pacific saury boats in block C in 2002, 2004, 2005 and 2006 were 403, 36, 47 and 25, respectively. Average SST at the positions of commercial Pacific saury fishing boats in block C in 4 years was 14.7. The influx of common minke whales to the Kushiro waters was coincided with the influx of Pacific saury which was one of major preys of them. But it was difficult to distinguish whether timing of migration of common minke whales was regulated by oceanographic conditions, migration of Pacific saury, or combination of both.

KEYWORDS: DISTRIBUTION, FEEDING MIGRATION, MINKE WHALE, NORTH PACIFIC, OYASHIO, PACIFIC SAURY.

INTRODUCTION

It is recognized that the distribution of common minke whales (*Balaenoptera acutorostrata*) off Kushiro Hokkaido, Japan in September is related to the distribution of Pacific saury (*Cololabis saira*) (Tamura and Fujise, 2002). Because common mike whales actively feed a variety of species off Kushiro in September, it is considered that they are still on the course of feeding migration from north to south. The first branch of Oyashio, the subarctic western boundary current with cold low-salinity water, is extended to Kushiro water from east side as season progress from summer to autumn but the shape and the extent show year to year variations. Fishing grounds of Pacific saury off Kushiro in September was related to the positions of the Oyashio front (5 °C water temperature isotherm at 100m) and their positions were shifted as the positions of Oyashio front showed yearly variations (Yasuda and Kitagawa, 1996). Schematic map of oceanographic futures in the western North Pacific was shown in Fig. 1 (Yasuda, 2003). Sea surface temperature (SST) is better indicator for positions of fishing ground of Pacific saury. It was reported that mode of SST at the fishing sites of Pacific saury in this region was 15 °C (Watanabe *et al.*, 2006). Given those evidences, migration pass of common minke whales off Kushiro in September could follow the seasonal extent of Oyashio and/or southbound migration of Pacific saury. In this paper, we investigate the relationship between the oceanographic conditions and the distribution of common minke whales off Kushiro in September. Specifically, the aims of this paper are to report (1) whether the influx of common minke whales to Kushiro water in September is related to SST and (2) whether the distribution pattern of common minke whales is related to distribution patterns of the fishing sites of Pacific saury.

MATERIALS AND METHODS

Sighting surveys of common minke whales were conducted off Kushiro, Hokkaido Japan in 2002, 2004, 2005 and 2006 as a part of the coastal component of the Japanese Whale Research Program under Special Permit in the western North Pacific Phase II (JARPN II). Longitudinal boundaries of the survey area were set at 143°15’E and at 146°E while latitudinal boundaries were set at the 50 m isobath and at 41°N (Fig. 2). Surveys were conducted in September (Table 1). The survey area was stratified into two: offshore and coastal strata. The boundary between those strata was set at 60 n.miles isodistance from coast line of Hokkaido. Additonal straum off Hidaka sub-prefecture (between 142°30’E and 143°15’E) was surveyed in 2005 and 2006. Coastal stratum was further divided into three strata. Stratified survey blocks were Offshore (O), coastal-East (E), coastal-Central (C), coastal-West (W), and off Hidaka sub-prefecture (H). A sighting survey vessel (SV), Kyoshin-Maru #2 (372 GT), engaged in the sighting surveys. Primary observers were allocated to the top barrel (3 observers) and the upper bridge. (2 observers). Zigzag tracklines were constructed within the survey area. Sampling survey of minke whales by small –type whaling catcher boats within 30 n.miles from the Kushiro port was conducted independently from the sighting survey. Sighting survey was also conducted within 30 n.miles from the Kushiro port as a part of the surveys in block C. Area within 30 n.miles from the Kushiro port was term as Kushiro block (K) as a post-stratified block in this paper. The starting points of tracklines were selected randomly. The sighting survey was conducted during daylight hours. The nominal steaming speed of SV on the tracklines was 10 knot. Closing mode was applied in 2002 and in 2004 while passing mode was applied in 2005 and in 2006. In the passing mode, abeam closing was conducted if the species of sightings were uncertain. Because school size of common minke whales off Kushiro is generally 1 individual, application of passing mode is adequate. School/individual density index (DI, the numbers of schools/individuals divided per 100 n.miles) was calculated for each survey block in each year as an indicator of the extent of the influx of common minke whales to Kushiro water. Average SST at the time of each sighting was summarized by each block in each year.

The number of position of commercial Pacific saury fishing boats was summarized by each block in each year as an indicator of presence of Pacific saury. The data were prepared by the Japan Fisheries Information Service Center (JAFIC). Monthly data from August to October were used in this analysis. Although sighing survey of common minke whales was conducted only in September, data in August and September were also used to see whether seasonal changes of fishing ground of Pacific saury showed yearly fluctuations.

SST data derived from a satellite, Moderate Resolution Imaging Spectroradiometer (MODIS)

Aqua, were used to depict oceanographic condition. Daytime, Level-3 Standard Mapped Images were used. Data were firstly extracted using The SeaWiFS Data Analysis System (SeaDas 4.0) developed at the NASA Goddard Space Flight Center, USA.

Data of sightings, positions of fishing boats and SST were overlaid using a geographic information system (GIS) "Marine Explorer version 4" (Environment Simulation Laboratory, Japan). The area in 1 °C SST increment was also calculated using the GIS.

RESULTS

Entire survey area

The surveyed tracklines and the sighting positions of common minke whales were overlaid on the SST maps (Fig. 3). The fishing positions of commercial Pacific saury fishing boats in September in 2002, 2004, 2005 and 2006 were overlaid on the SST maps (Fig. 4). Those maps suggested that overall SST in the survey area was getting higher from 2002 to 2006. Mean SST was increased from 17.3 °C in 2002 to 19.4 °C in 2006 (Table 2). Frequency of number of sightings of common minke whales by SST (1 °C increment) was shown in (Fig. 5). Average SST in 4 years at the positions of the sightings of common minke whales was 15.5 (CV=12.4%, n=87) while it in 2006 was 19.1 (CV=6.0%, n=12) (Table 2). Frequency of number of the Pacific saury fishing boats by SST (1°C increment) was shown in (Fig. 6). Mean SST in 4 years at the fishing positions of commercial Pacific saury boats was 15.1 (CV=10.2%, n=2646) while it in 2006 was 16.4 (CV=10.3%, n=450) (Table 2). The number of fishing boats was less in 2006. Frequency of area (n.mile^2) of SST ≤ 16 °C and 16 °C < in all survey blocks in September in 2002, 2004, 2005 and 2006 was summarized in Fig. 7. Because mean SST at the sighing positions of common minke whales was 15.5, 16 was selected as a cut point. Area of SST ≤ 16 °C was shrinking as year progress. DI was lowest in 2006 (Table 2).

Block K and C

Overall patterns of the SST distributions, the sightings of minke whales and the positions of commercial Pacific saury fishing boats in blocks near the Kushiro port (K and C) were similar to those in entire survey area (Table 2 and Figs. 8 and 9). Average SST in Block C in 4 years at the positions of sightings of common minke whales was 15.1 (CV=10.1%, n=60) while it in 2006 was 18.7 (CV=3.9%, n=5) (Table 2). Mean SST in 4 years at the fishing positions of commercial Pacific saury boats was 14.7 (CV=7.4%, n=511) while it in 2006 was 15.7 (CV=0.8 %, n=25). In 2002, 15.0 °C isotherm SST front was remained in block K and C and it was not extended to block E (Fig. 3). In 2006, 15.0 °C isotherm SST front was not observed in 2006. In 2004, 15.0 °C isotherm SST front was extended to block W. In 2005, 15.0 °C isotherm SST front was remained eastern part of blocks K and C. DIs in block C decreased from 2002 to 2006 as the average SST in the block increased. Because the coverage of the sighting effort in block K was insufficient and heterogeneous in each year, inter-year comparisons of DIs were difficult. Though SST in block K was as in the case of the entire survey area as well as block C, DIs didn't decreased in consistent manner. But DIs in 2006 were lower than that in 2002. Frequency of area of SST ≤ 16 °C in blocks K and C was decreased from 2002 to 2006.

Blocks other than K and C

Few sightings were made in blocks O and H where average SSTs were high regardless of years (Table 2). DI was highest in block W in 2002 when 15.0 °C isotherm SST front was intruded in the block (Fig. 3). DI in block E 2004 was low in comparisons with other years. In the rest of years (2002, 2005, 2006) 15.0 °C isotherm SST front was not extended to block W. Especially in 2005 and 2006, DIs in block E were higher than that in block C.

Oceanographic conditions and fishing boats operation in August and October

Maps of SST in August and October in 2002, 2004, 2005 and 2006 were shown in Fig. 10. Positions of commercial Pacific saury fishing boats were overlaid in the maps. SST in the Kushiro water was high in August except 2002. In 2002, SST off Kushiro was already low enough to operate commercial Pacific saury fishing boats. SST was decreased from August to September in each year but magnitude of lowering was slow in 2002. SST continuously decreased from September to October. Average temperature in October in 2006 was similar to the rest of years (Table 3). Abrupt shift of fishing positions of commercial pacific saury fishing boats from Hokkaido to Sanriku was observed in 2006.

DISCUSSION

As in the case of Pacific saury, influx of common minke whales to the Kushiro water was regulated by SST. Few common minke whales migrated to the Kushiro water when SST was higher than 15 °C. It was reported that mode of SST at the Pacific saury fishing boat operation sites was 15 °C (Watanabe *et al.*, 2006). Timing of migration of Pacific saury to the Kushiro water showed remarkable change as the oceanographic conditions showed yearly fluctuations (Fukushima, 1979). Migration cue to the Kushiro water for both common minke whales and Pacific saruy was same. At this stage, it was difficult to distinguish whether timing of migration of common minke whales was regulated by oceanographic conditions, migration of Pacific saury, or combination of both. Lower DIs of common minke whales in September in 2006 can be explained by high SST in the Kushiro water.

Pacific saury continues southbound migration in October. Pacific saury migrates to the Sanriku water when SST was below 20 °C (Watanabe *et al.*, 2006). Model predictions suggested that catch of Pacific saury in the Kushiro water was highest in mid to late September and substantially decreased in October and catch in the Sanriku water increased as the result of migration (Watanabe *et al.*, 2006). Timing of migration from the Kushiro water to the Sanriku Water was also regulated by the oceanographic conditions and changed year to year (Yasuda and Watanabe, 1994). In general, migration of Pacific saury from the Kushiro water to the Sanriku water is continuous as in the cases in 2002 and 2005. But the positions of commercial Pacific saury fishing boats showed abrupt shift from the Kushiro water to the Sanriku water in 2006. Probably, the abrupt shift of the fishing positions could be related to the rapid decrease of SST October 2006 though it was not detected in this analysis because monthly SST data were used. It can be hypothesised that common minke whales continue their southbound migration as in the case of Pacific saury. If that is the case, number of common minke whales could change given the oceanographic conditions. Because of scarcity of distribution data of common minke whales after October, it is difficult to conclude it at this stage.

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Table 1. Survey periods.

Year	Start	End
2002	11 Sep	27 Sep
2004	10 Sep	27 Sep
2005	2 Sep	19 Sep
2006	1 Sep	20 Sep

Table 2. Summary of sightings of common minke whales, SST in surveyed area and commercial Pacific saury fishing boats in the survey area. Note that the number of commercial Pacific saury fishing boats on the boundary lines of survey blocks were counted for both blocks thus total number of each blocks slightly exceed the numbers in all blocks. DI is the number of school/individuals per 100 n.miles.

Year	Common minke whale sighting survey						SST in survey blocks (MODIS-Aqua)			Commercial Pacific saury boats	
	Effort (n.miles)	Sch.	Ind.	Avg. SST (°C)	DI (Sch.)	DI (Ind.)	Avg. SST (°C)	Area ≤16ºC (%)	Area 16ºC< (%)	# of boats	Avg. SST (°C)
All Blocks											
2002	681.5	38	40	14.3	5.6	5.9	17.3	55.1	44.9	1815	14.8
2004	809.4	17	18	15.4	2.1	2.2	17.4	35.8	64.2	256	14.9
2005	827.1	20	21	15.6	2.4	2.5	18.7	10.2	89.8	125	15.5
2006	994.0	12	12	19.1	1.2	1.2	19.4	3.6	96.4	450	16.4
Block K											
2002	66.2	11	12	14.4	16.6	18.1	15.8	100.0	0.0	22	13.9
2004	89.9	5	6	15.6	5.6	6.7	16.2	94.2	5.8	7	15.4
2005	145.5	5	5	15.8	3.4	3.4	16.9	58.5	41.5	36	14.9
2006	85.0	4	4	19.0	4.7	4.7	18.0	8.2	91.8	0	-
Block C											
2002	272.6	33	34	14.4	12.1	12.5	16.0	92.5	7.5	403	14.6
2004	238.7	12	13	15.5	5.0	5.4	16.3	80.7	19.3	36	15.0
2005	365.3	10	11	15.4	2.7	3.0	17.7	22.9	77.1	47	15.0
2006	247.4	5	5	18.7	2.0	2.0	18.5	3.8	96.2	25	15.7
Block E											
2002	73.5	5	6	13.8	6.8	8.2	15.7	100.0	0.0	431	14.2
2004	140.6	1	1	15.1	0.7	0.7	15.2	97.6	2.4	56	15.0
2005	127.7	9	9	15.3	7.0	7.0	17.2	42.5	57.5	81	15.5
2006	145.0	5	5	18.9	3.4	3.4	17.9	24.2	75.8	324	16.5
Block W											
2002	48.2	0	0	-	0.0	0.0	18.0	6.9	93.1	305	15.2
2004	164.9	3	3	14.9	1.8	1.8	17.4	34.2	65.8	59	15.6
2005	180.3	1	1	20.7	0.6	0.6	18.4	5.0	95.0	0	-
2006	161.9	1	1	20.0	0.6	0.6	19.3	0.0	100.0	4	16.7
Block O											
2002	287.2	0	0	-	0.0	0.0	17.1	62.4	37.6	664	15.0
2004	265.2	1	1	17.4	0.4	0.4	17.7	9.0	91.0	105	14.5
2005	41.7	0	0	-	0.0	0.0	19.0	0.0	100.0	7	18.1
2006	285.3	0	0	-	0.0	0.0	20.1	0.0	100.0	98	16.2
Block H											
2002	-	-	-	-	-	-	19.9	0.0	100.0	17	16.9
2004	-	-	-	-	-	-	20.1	0.0	100.0	0	-
2005	112.1	0	0	-	0.0	0.0	20.9	0.0	100.0	0	-
2006	154.4	1	1	21.3	0.6	0.6	20.1	0.0	100.0	0	-

Table 3. Average SST in each survey block in September and October in 2002, 2004, 2005 and 2006. The numbers of commercial Pacific saury fishing boats and the average SST at the operation sites are also shown.

Year	Average SST (MODIS-Aqua)		Commercial Pacific suary boats			
			Sep.		Oct.	
	Sep. (°C)	Oct. (°C)	# of boats	Avg. SST (°C)	# of boats	Avg. SST (°C)
All Blocks						
2002	17.3	14.7	1815	14.8	398	12.7
2004	17.4	15.0	256	14.9	284	14.1
2005	18.7	16.2	125	15.5	171	14.7
2006	19.4	14.7	450	16.4	156	13.2
Block K						
2002	15.8	12.9	22	13.9	13	12.5
2004	16.2	13.9	7	15.4	101	14.3
2005	16.9	14.4	36	14.9	15	14.3
2006	18.0	13.4	0	-	6	14.7
Block C						
2002	16.0	13.2	403	14.6	67	12.7
2004	16.3	13.8	36	15.0	149	14.1
2005	17.7	14.6	47	15.0	55	14.5
2006	18.5	13.6	25	15.7	43	14.9
Block E						
2002	15.7	13.1	431	14.2	206	12.5
2004	15.2	14.1	56	15.0	90	14.2
2005	17.2	14.9	81	15.5	51	14.4
2006	17.9	12.2	324	16.5	70	12.1
Block W						
2002	18.0	14.5	305	15.2	50	12.5
2004	17.4	14.9	59	15.6	23	14.2
2005	18.4	15.8	0	-	45	15.2
2006	19.3	15.2	4	16.7	10	16.2
Block O						
2002	17.1	14.8	664	15.0	83	13.1
2004	17.7	14.9	105	14.5	21	14.4
2005	19.0	16.8	7	18.1	19	14.6
2006	20.1	14.7	98	16.2	33	12.3
Block H						
2002	19.9	18.2	17	16.9	-	-
2004	20.1	17.8	0	-	6	14.1
2005	20.9	18.4	0	-	7	15.5
2006	20.1	17.3	0	-	-	-

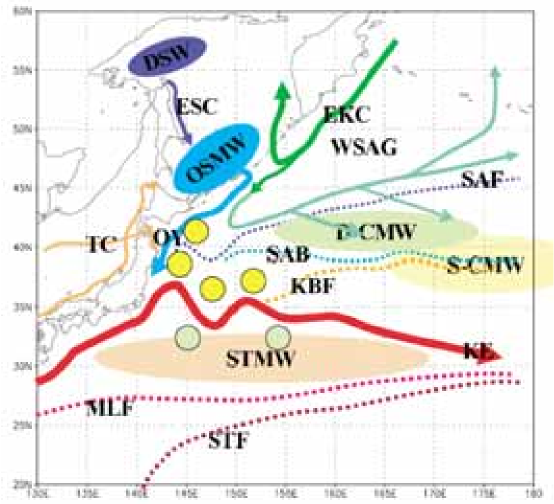


Fig. 1. Schematic map of surface current, fontal structure and water mass in the western North Pacific. This is Fig.1 of Yasuda (2003). EKC: East Kamchatka Current, WSAG: Western Subarctic Gyre, ESC: East Shakalin Current, OY: Oyashio, KE: Kuroshio Extension, TC: Tsushima Warm Current, SAF: Subarctic Front, SAB: Subarctic Boundary, KBF: Kuroshio Bifurcation Front, STF: Subtropical Mode Water, S-CMW: Shallow Central Mode, D-CMW: Dense Central Mode Water, DSW: Dense Shelf Water, OSMW: Okhotsk Sea Mode Water, Yellow circles: warm-core rings, Light green circles: cold-core rings.

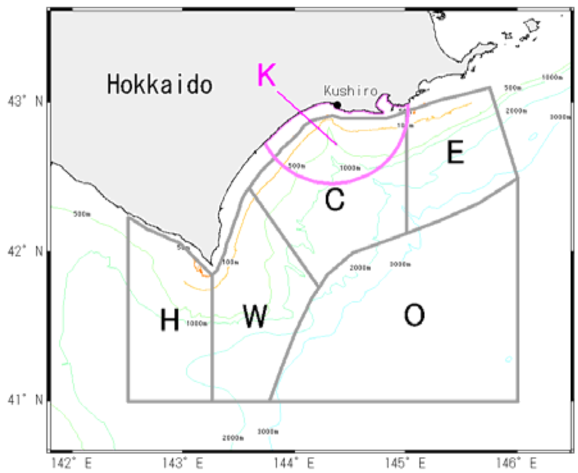


Fig. 2. Surveyed blocks off Kushiro: Offshore (O), coastal-East (E), coastal-Central (C), coastal-West (W), off Hidaka sub-prefecture (H) and Kushiro block (K).

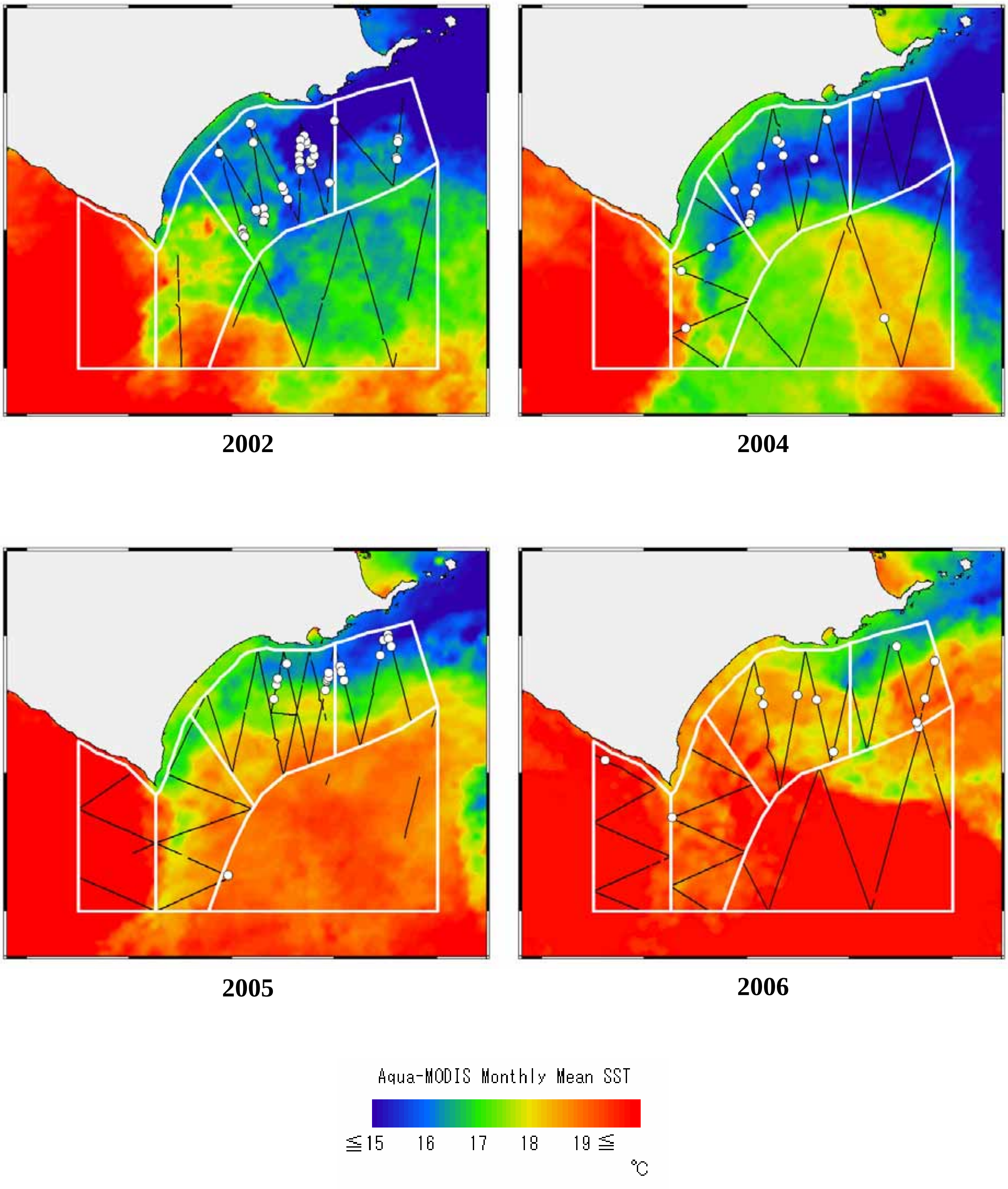


Fig. 3. Surveyed tracklines (black lines) and sighing positions of common minke whales (open circles) off Kushiro in September in 2002, 2004, 2005 and 2006. Monthly mean SST derived from Aqua-MODIS is also shown. White line represents the boundary of survey blocks.

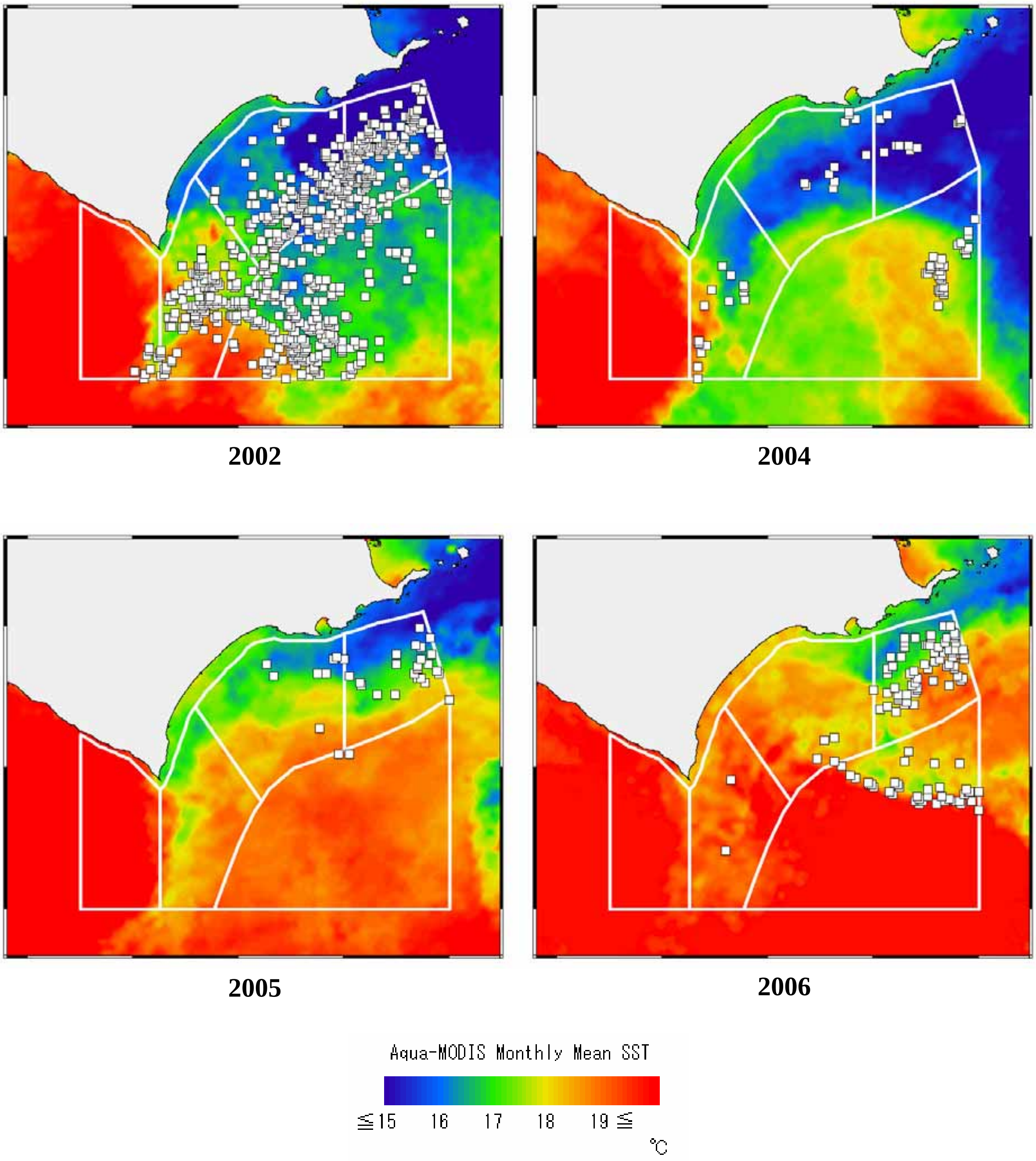
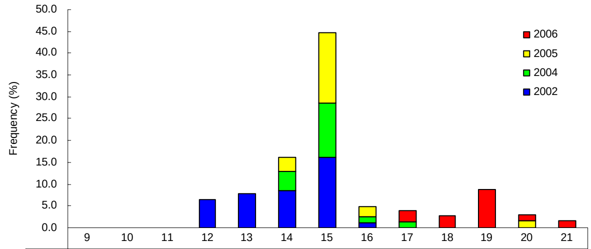
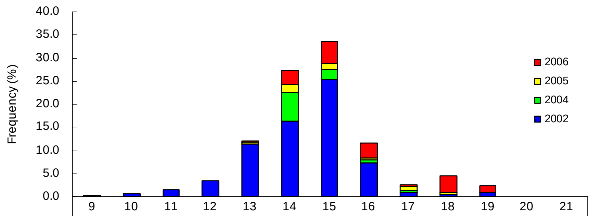


Fig. 4. Fishing positions of commercial Pacific saury fishing boats (open square) in September in 2002, 2004, 2005 and 2006. Monthly mean SST derived from Aqua-MODIS is also shown. White line represents the boundary of survey blocks.



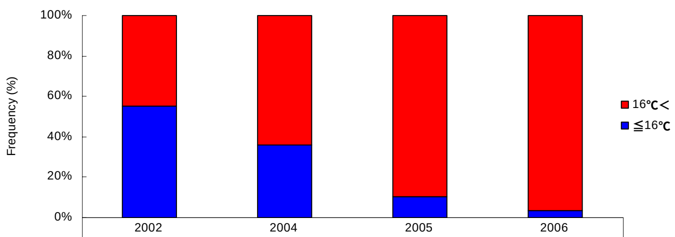
SST (℃)	9	10	11	12	13	14	15	16	17	18	19	20	21
2006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	2.8	8.7	1.5	1.6
2005	0.0	0.0	0.0	0.0	0.0	3.2	16.0	2.4	0.0	0.0	0.0	1.5	0.0
2004	0.0	0.0	0.0	0.0	0.0	4.3	12.6	1.2	1.3	0.0	0.0	0.0	0.0
2002	0.0	0.0	0.0	6.4	7.9	8.6	16.0	1.2	0.0	0.0	0.0	0.0	0.0

Fig. 5. Frequency of numbers of sightings of common minke whales by SST (1 °C increment) in all survey blocks in September in 2002, 2004, 2005 and 2006. SST at the positions of sightings were used.



SST (℃)	9	10	11	12	13	14	15	16	17	18	19	20	21
2006	0.0	0.0	0.0	0.0	0.2	3.2	4.6	3.3	0.6	3.7	1.5	0.0	0.0
2005	0.0	0.0	0.0	0.0	0.3	1.5	1.4	0.5	0.8	0.2	0.0	0.0	0.0
2004	0.0	0.0	0.0	0.0	0.1	6.4	2.2	0.5	0.5	0.0	0.0	0.0	0.0
2002	0.3	0.7	1.6	3.4	11.4	16.3	25.3	7.4	0.9	0.5	0.8	0.1	0.0

Fig. 6. Frequency of numbers of commercial Pacific saury boats by SST (1 °C increment) in all survey blocks in September in 2002, 2004, 2005 and 2006. SST at the positions of sightings were used.



Year	2002	2004	2005	2006
16℃<	44.9	64.2	89.8	96.4
≦16℃	55.1	35.8	10.2	3.6

Fig. 7. Frequency of area (n.mile^2) of SST ≤ 16 °C and 16 °C < in all survey blocks in September in 2002, 2004, 2005 and 2006.

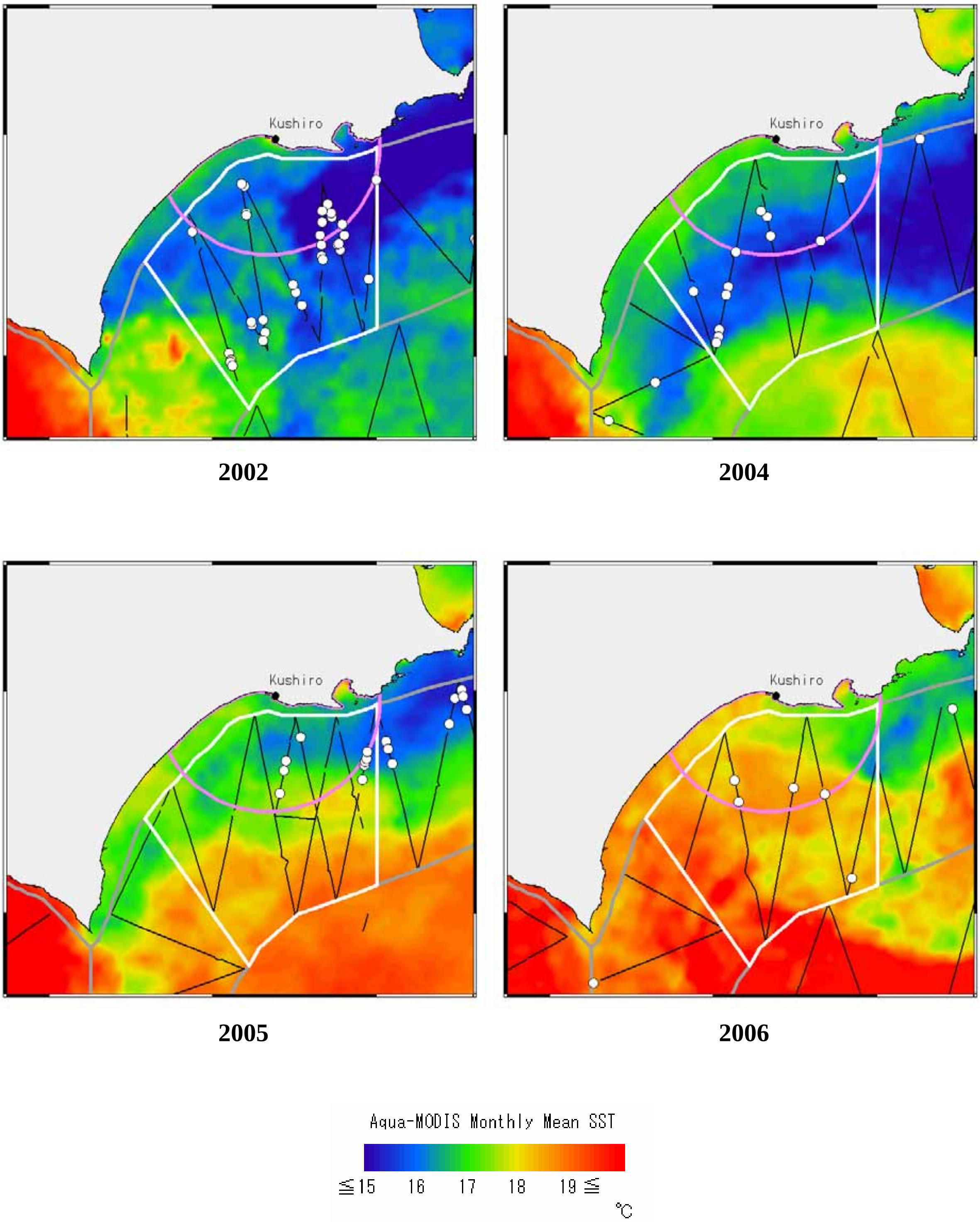


Fig. 8. Surveyed tracklines (black lines) and sighing positions of common minke whales (open circles) in Block C and K in September in 2002, 2004, 2005 and 2006. Monthly mean SST derived from Aqua-MODIS is also shown. White line represents the boundary of block C while pink line represents the boundary of block K.

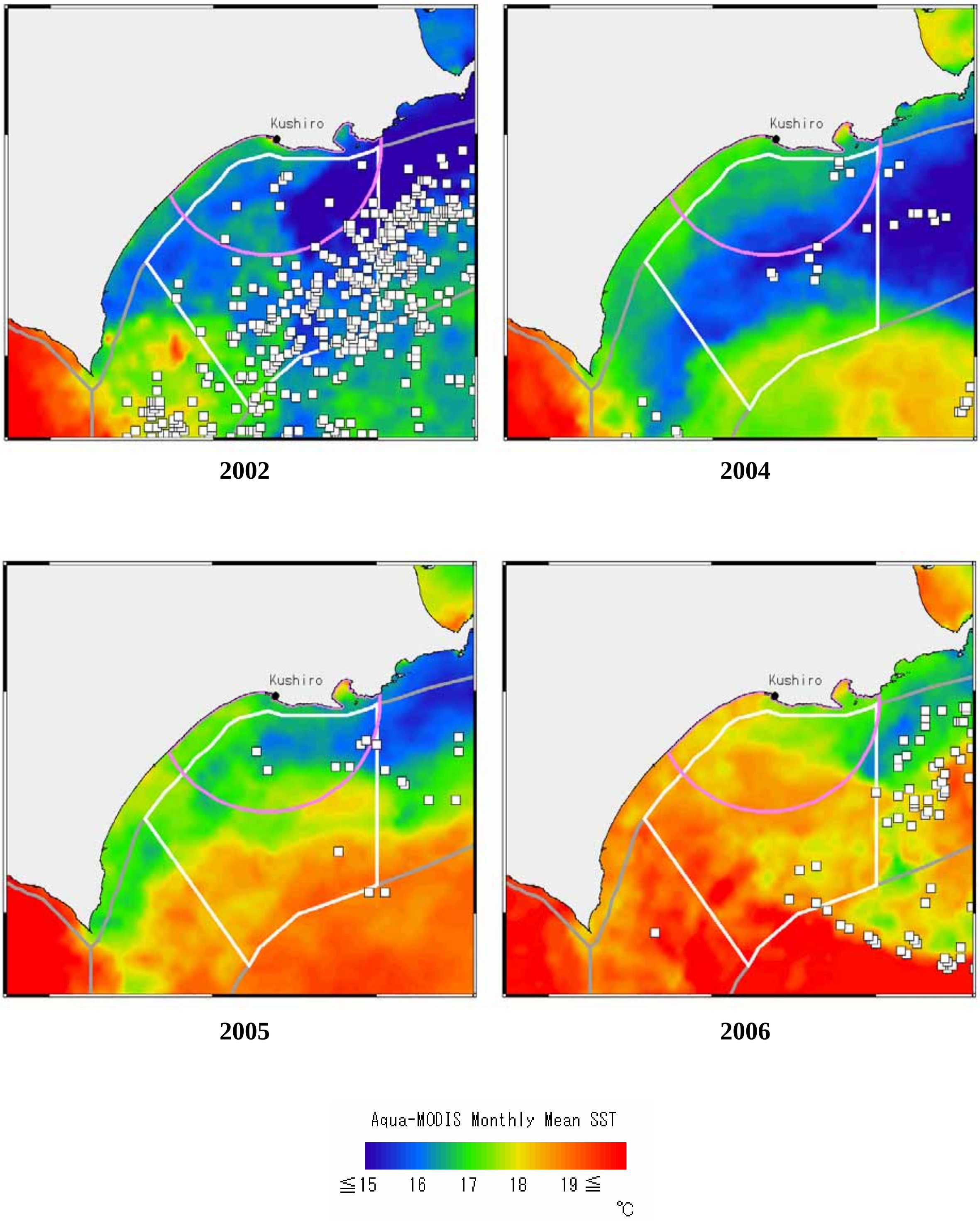


Fig. 9. Fishing positions of commercial Pacific saury fishing boats (open square) in September in 2002, 2004, 2005 and 2006. Monthly mean SST derived from Aqua-MODIS is also shown. White line represents the boundary of block C while pink line represents the boundary of block K.

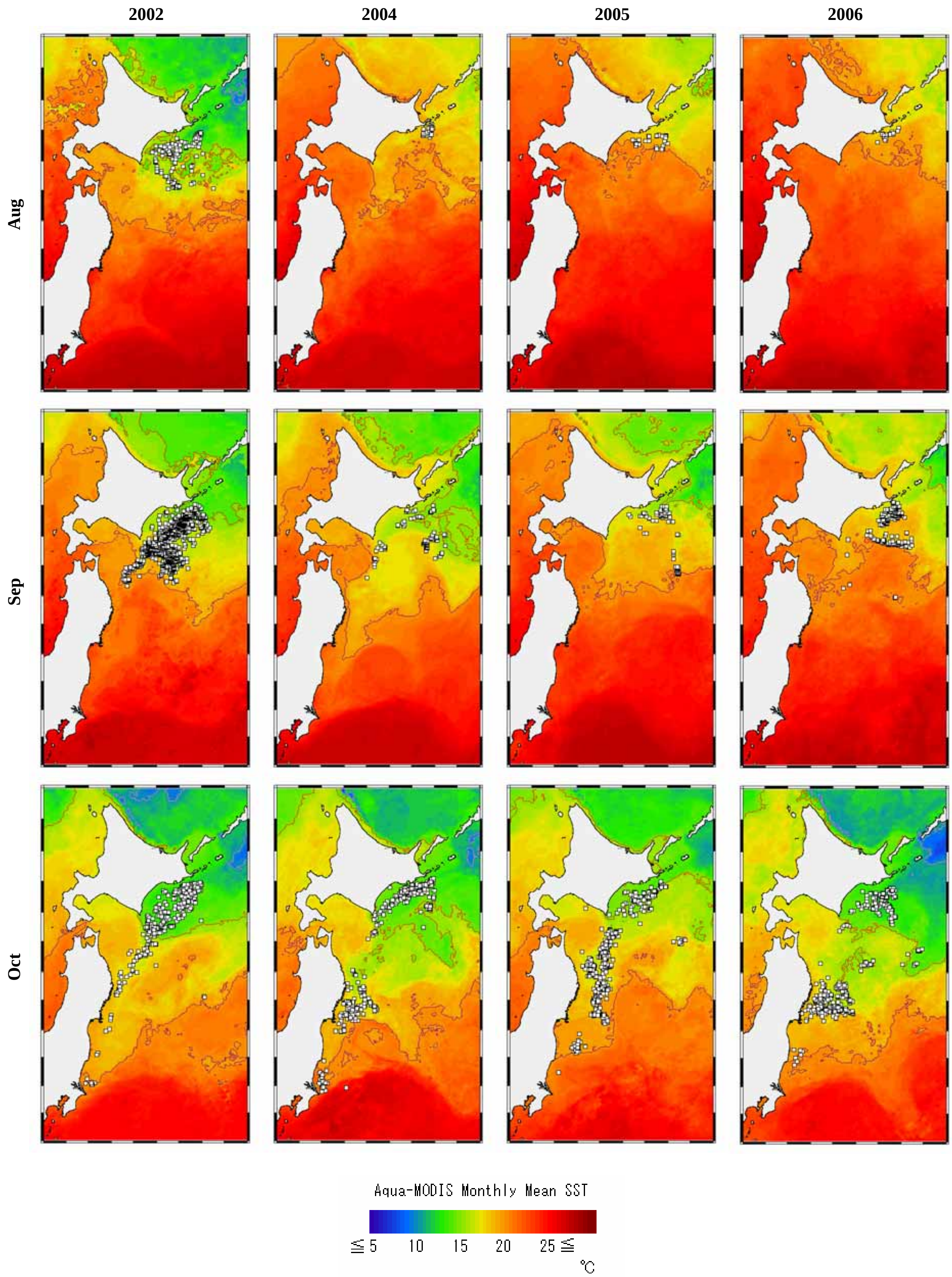


Fig. 10. Fishing positions of commercial Pacific saury fishing boats (open square) in August, September and October in 2002, 2004, 2005 and 2006. Monthly mean SST derived from Aqua-MODIS is also shown. Red line represents 15.0°C SST isotherm while purple line represents 20.0°C SST isotherm.