Prey consumption and feeding habits of common minke whales in coastal areas off Sanriku and Kushiro

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ABSTRACT

The stomach contents of common minke whales *Balaenoptera acutorostrata* sampled off Sanriku from April to May and Kushiro region from September to October in 2002-2007 JARPN II were analyzed. In Sanriku region, the dominant prey species consisted of one krill (*Euphausia pacifica*) and two fishes (Japanese sand lance *Ammodytes personatus* and Japanese anchovy *Engraulis japonicus*). On the other hand, in the Kushiro region, the dominant prey species consisted of one krill (*E. pacifica*), three fishes (Japanese anchovy, Pacific saury *Cololabis saira* and walleye pollock *Theragra chalcogramma*) and one squid (Japanese flying squid *Todarodes pacificus*). All these prey species are targeted by local fisheries. In Sanriku region, the yearly compositions of Japanese sand lance, Japanese anchovy and krill in wet weight were 58.8–84.2 %, 0.0–39.5 % and 0.1–37.9 %, respectively. In Kushiro region, the yearly compositions of Pacific saury, walleye pollock, Japanese flying squid and Japanese anchovy in wet weight were 1.2–40.6 %, 3.6–71.5 %, 0.1–33.8 % and 9.5–60.6 %, respectively. The estimated daily prey consumption of immature male, immature female, mature male and mature female were 78-118kg, 73-114kg, 107-224kg and 133-270kg, respectively. The total prey consumption in the Sanriku region of Japanese sand lance, Japanese anchovy and Krill by common minke whales was estimated as 1,616 and 683 tons, 194 and 150 tons, 109 and 1 tons per year in 2005 and 2006 seasons, respectively. The consumption of sand lance by minke whales was equivalent to 18.7 and 12.3 % of the 2005 and 2006 fisheries catch, respectively. Distribution of common minke whale in Sendai Bay overlapped Japanese sand lance fisheries ground. In Kushiro region, the total prey consumption of Pacific saury, walleye pollock and Japanese flying squid and Japanese anchovy by common minke whales was estimated as 39–1,075 tons, 95–2,322 tons 3-1,753 tons and 308–1,422 tons per year, respectively. The consumption of Pacific saury, walleye pollock and Japanese flying squid by minke whales were equivalent to 0.1-1.8 %, 0.1-3.6 % and 0.1-117.1 % of fisheries catch, respectively.

KEYWORDS: COMMON MINKE WHALE; SANRIKU; KUSHIRO; NORTH PACIFIC; FISHERIES INTERACTION, SCIENTIFIC PERMIT

INTRODUCTION

The common minke whale *Balaenoptera acutorostrata* is widely distributed in the world. In the western North Pacific, two stocks have been recognized: one in the Sea of Japan - Yellow Sea - East China Sea (J stock) and the another in the Sea of Okhotsk – West Pacific (O stock) (IWC, 1983). The abundance of common minke whales was estimated to be 19,209 animals with 95 %

confidence interval (10,069 – 36,645) in the Sea of Okhotsk and 5,841 animals with 95 % confidence interval (2,835 – 12,032) in the Northwest Pacific during August and September in 1989 and 1990 (IWC, 1992). In the western North Pacific, common minke whales are opportunistic feeders consuming a broad of prey with flexible feeding habits. According to previous reports, they consume several prey species such as pelagic schooling fish and zooplankton (Kasamatsu and Hata, 1985; Kasamatsu and Tanaka, 1992; Tamura *et al*., 1998, Tamura and Fujise, 2002a).

The results of the Japanese Whale Research Program under Special Permit in the Western North Pacific (JARPN) and JARPN II feasibility study showed that common minke whales fed on various prey species such as Japanese anchovy *Engraulis japonicus*, Pacific saury *Cololabis saira*, walleye pollock *Theragra chalcogramma* and Japanese flying squid *Todarodes pacificus*, and the main prey species changed seasonally and geographically. For example, they feed on Japanese anchovy in May/June and Pacific saury in July/August (Tamura and Fujise, 2000a, 2002b). The estimated prey consumption by common minke whales was comparable to that of the commercial fisheries (Tamura and Fujise, 2000b, 2002c), indicating the interaction between common minke whales and fisheries may occur in the coastal area.

However, the *Nisshin-Maru* and large sighting/sampling vessels can not be operated in the near shore area because of various restrictions and obstacles. Furthermore, these vessels can not join survey in late autumn and early spring for operational reason. In order to cover the geographical and seasonal gaps of JARPN and JARPN II feasibility study, sampling of common minke whales in the coastal area using small type whaling catcher boats was planed in 2002 (Government of Japan, 2002). Off Sanriku region, the coastal component of JARPN II was conducted in April and May. On the other hand, in Kushiro region, the coastal component of JARPN II was conducted in September and October. In this document, the abundance of common minke whales and the consumption of targeted fisheries species by common minke whales were calculated using some assumption off Sanriku and Kushiro regions. Then, the prey consumptions by common minke whales and fisheries catches were compared.

MATERIALS AND METHODS

Research area, year, season and sample size

Sanriku region

The sampling area covers within the 30 n.miles (maximum 50 n.miles) from the Ayukawa port (Fig.1). The researches were conducted in April and May from 2003 to 2007. The sample size for the minke whale in the Sanriku component started 50 animals in 2003. After 2004, the sample size changed to 60 animals to be taken in every spring (April and May). These surveys were described in detail by Kishiro *et al*. (2009).The actual sampling number of whales between 2003 and 2007 is shown in Table 1.

Kushiro region

The study area was covered north of 41N and longitude from 143.15E (Cape Erimo) to 146E. The sampling area covers within the 30 n.miles (maximum 50 n.miles) from the Kushiro port (Fig.1). The researches were conducted in September and October from 2002 to 2007. The sample size for the minke whale in the Kushiro component started 50 animals in 2003. After 2004, the sample size changed to 60 animals to be taken in every autumn (September and October). These surveys were described in detail by Kishiro *et al*. (2009).The actual sampling number of whales between 2002 and 2007 is shown in Table 1.

Sampling of stomach contents of minke whales

Baleen whales have four chambered stomach system (Hosokawa and Kamiya, 1971; Olsen *et al.*, 1994). The stomach contents remain in the forestomach (1st. stomach) and fundus (2nd. stomach). Therefore, this study was based on contents from forestomach and fundus.

The stomach contents were removed at the research land station. Then, contents were weighed to the nearest 0.1 kg. A sub-sample (1-5 kg) of stomach contents was removed and frozen and/or fixed with 10 % formalin water for later analyses. The stomach contents were transferred to a system consisting of three sieves (20 mm, 5 mm and 1 mm), which were applied in the Norwegian scientific research to filter off liquid from the rest of the material (Haug *et al.* 1995). The sub-sample (3-4 kg) included all undigested fish skulls, free otoliths and squid beaks, which were kept frozen for later analyses in the laboratory.

Data analyses

Prey species identification and restoring stomach contents weight

In the laboratory prey species in the sub-samples were identified to the lowest taxonomic level as possible. Undigested preys were identified using morphological characteristic of copepods (Brodskii, 1950), euphausiacea (Baker *et al*., 1990), squids (Kubodera and Furuhashi, 1987) and fish (Masuda *et al*., 1988; Chihara *et al.*, 1997). The otoliths and jaw plate were used to identify the fish and squid with advanced stage of digestion (Morrow, 1979; Ohe, 1984; Kubodera and Furuhashi, 1987; Arai, 1993).

When undigested fish and squid were found, fork length, mantle length and the weights were measured to the nearest 1 mm and 1 g, respectively. This data were used for restoring their stomach contents with advanced stage of digestion.

The total number of each fish and squid species in the sub-sample were calculated by adding to the number of undigested fish or squid, undigested skulls and half the total number of free otoliths. The total weight of each prey species in the sub-sample was estimated by multiplying the average weight of fresh specimens by the number of individuals. The total number and weight of each prey species in the stomach contents were estimated by using the figures obtained from the sub-sample and the total weight of stomach contents. The total weight of each zooplankton was estimated by using an assimilation efficiency of 84 % (Lockyer, 1981).

Prey composition in each year

In order to simplify the comparison of feeding indices, prey species were divided into the following prey groups: krill (*Euphausia pacifica*), Japanese anchovy, Japanese sand lance, Pacific saury, walleye pollock, Japanese pomfret (*Brama japonica*), Salmonids, Japanese flying squid and other fishes.

The relative prey composition (%) in weight of each prey species (*RW*) in each month was calculated as follows:

$RW_i = (W_i / W_{all}) \times 100$

W_i = the weight of contents containing prey group i

W_{all} = the total weight of contents analyzed.

Estimation of daily and seasonal prey consumption in each whale species

The daily consumption of each prey species (*D*) by different maturity stages of minke whale were calculated from the following equations (Sigurjónsson and Víkingsson, 1997):

$D = 206.25M^{0.783}$; $F = D/E$

D : Daily prey consumption (kcal day^{-1})

M: Mean body weight of whales (kg)

F : Daily prey consumption (kg day^{-1})

E : Caloric value of prey species (kcal kg^{-1})

The following figures and assumptions were used for this method.

A: Mean body weight (M)

In Sanriku region, the mean body weight of 2,080 kg and 2,120 kg for immature male and female of minke whale were calculated, respectively. For mature male and female of minke whale were 4,060 kg and 5,330 kg, respectively. In Kushiro region, the mean body weight of 2,130 kg and 1,980 kg for immature male and female of minke whale were calculated, respectively. For mature male and female of minke whale were 4,830 kg and 6,140 kg, respectively. These weights were obtained from JARPN II survey data.

B: Caloric value of prey species (E)

Stomach contents analyses show large variations in the diet of baleen whales in the western North Pacific (Kasamatsu and Tanaka, 1992; Tamura et al., 1998). In the North Atlantic, the energy contents of the prey species varies from 900 kcal kg-1 when feeding on *Parathemisto* spp. to as high as 3,000 kcal kg^{-1} when feeding on herring (Markussen *et al*., 1992). In this study, the mean caloric value of copepods, krill, Japanese anchovy, Pacific saury, walleye pollock and Japanese flying squid were calculated using bomb caloric meter (Table 2).

C: Residence time in the western North Pacific (D)

It was assumed that the minke whales spend about 150 days in the feeding areas in the western North Pacific. These assumptions for estimating the feeding days were used. Lockyer (1981) indicated that around 83% of the annual energy intake in southern Hemisphere balaenopterids is ingested during the summer season, corresponding to approximately ten times higher feeding rates during feeding season of summer than non-feeding season of winter.

Based on this assumption, the average daily prey consumption during feeding season (SF), and during non-feeding season (NF) were made for the baleen whales by the following equations:

$SF = 2.020\ F$

$NF = 0.289\ F$

The residence time of the common minke whale off Sanriku and Kushiro region was assumed to be 60 days, respectively

D: The composition of maturity stages of whales

The composition of maturity stages of whales was shown in Table 3. Sexually mature male of common minke whales were defined by testis weight (larger side) of more than 290g. Female had at

least one corpus luteum or albicans in their ovaries was determined as sexually mature (Kishiro *et al.*, 2009; Yoshida *et al.*, 2009).

E: The yearly number of whales distributed by each sexual maturity stage and area

The number of whales distributed in each area and year was described by Hakamada *et al.* (2009). In this study, the number of the minke whales distributed off Sanriku during the survey period was used only that of coastal strata. The yearly number of whales distributed in each sexual maturity stage and area is estimated in Table 4.

RESULTS

Diversity and composition of prey species

Sanriku region

Three prey species consisting of 1 krill and 2 fish (Japanese sand lance and Japanese anchovy) were identified in stomachs of common minke whales caught off Sanriku region in 2003 - 2007 JARPNII. Japanese sand lance, Japanese anchovy and krill were dominant prey species and composed 58.8–81.9 %, 0.0–39.5 % and 0.1–37.9 % in wet weight (%), respectively (Table 5). Most minke whales (74 %) had fed upon one single prey species. Animal of 25.6 % had fed upon two species in the stomach (Table 6).

Kushiro region

The dominant prey species consisting of 1 krill (*Euphausia pacifica*), 3 fishes (Japanese anchovy, Pacific saury, and walleye pollock) and 1 squid (Japanese flying squid) were identified in common minke whales caught off Kushiro region in 2002 - 2007 JARPNII. Japanese anchovy, Pacific saury, walleye pollock and Japanese flying squid were dominant prey species and composed 9.5–60.6 %, 1.2–40.6 %, 3.6–71.5 % and 0.1-33.8 % in wet weight (%), respectively (Table 5). Most minke whales (67 %) had fed upon one single prey species. Animal of 27 % had fed upon two species and only 6.1% had more than two prey species in the stomach (Table 6).

The size distribution of three main prey consumed by common minke whales

Japanese sand lance

The size distributions of Japanese sand lance in the stomach of common minke whales are shown in Fig. 2-1. Minke whale feed on matured sand lance, the fork length ranged from 103 to 294 mm with a single mode at 130 mm.

Pacific saury

The size distributions of Pacific saury in the stomach of common minke whales are shown in Fig. 2-2. The fork length ranged from 127 to 342 mm with a bimodal mode at 150 mm and 250-270 mm.

Walleye pollock

The size distributions of walleye pollock in the stomach of common minke whales are shown in Fig. 2-3. The fork length ranged from 177 to 517 mm with a bimodal mode at 250 mm and 400 mm.

Japanese flying squid

The size distributions of Japanese neon flying squid in the stomach of common minke whales are shown in Fig. 2-4. The fork length ranged from 127 to 296 mm with a single mode at 210 mm.

Daily and seasonal prey consumption by whales

Sanriku region

The estimated daily prey consumption weights during feeding period off Sanriku region were 93-113 kg and 94-114 kg for immature male and female, and 156-190 kg and 193-236 kg for mature male and female, respectively (Table 7).

The total prey consumption in the Sanriku region of Japanese sand lance, Japanese anchovy and Krill by common minke whales was estimated as 1,616 and 683 tons, 194 and 150 tons, 109 and 1 tons per year in 2005 and 2006 seasons, respectively (Table 8).

Kushiro region

The estimated daily prey consumption weights during feeding period off Kushiro region were 78-118 kg and 73-111 kg for immature male and female, and 107-224 kg and 133-270 kg for mature male and female, respectively (Table 7).

The total prey consumption of Pacific saury, walleye pollock and Japanese flying squid and Japanese anchovy by common minke whales was estimated as 39–1,075 tons, 95–2,322 tons 3-1,753 tons and 308–1,422 tons per year, respectively (Table 8).

The feeding impact of fisheries resources

Sanriku region

Catch data of important commercial fish were provided from the Miyagi Prefecture Fisheries Technology Institute (2008). The catches of Japanese sand lance around the Sendai Bay from February to May in 2005 and 2006 seasons were 8,623 tons and 5,552 tons, respectively. The consumption of sand lance by minke whales was equivalent to 18.7 and 12.3 % of the 2005 and 2006 fisheries catch (Table 9).

Kushiro region

Catch data of important commercial fish were provided from the Hokkaido Government (2008). This data was the catch of the Kushiro blanch. The fisheries catches of Pacific saury, walleye pollock and Japanese flying squid in 2002-2006 were 48,403-61,895 tons, 52,524-75,041 tons and 1,497-5,042 tons per year, respectively. The consumption of Pacific saury, walleye pollock and Japanese flying squid by minke whales were equivalent to 0.1-1.8 %, 0.1-3.6 % and 0.1-117.1 % of fisheries catch, respectively (Table 9).

DISCUSSION

Sanriku region

Some sand lance species in the world have specific habit, summer aestivation (Robards *et al*, 1999). They hide themselves in near shore substrates every summer, when water temperature is high. In Sendai Bay, they hide during August and December, at mainly rough sand sediment in shallow water (< 50 m depth) (Kobayashi *et al*. 1991). So, Japanese sand lance as prey of common minke whale off Sanriku region is presumably available only from February to June through a year.

The dominant prey species of common minke whales sampled off Sanriku region in April and May were Japanese sand lance and followed Japanese anchovy and krill *Euphausia pacifica*. This result was similar to that of previous report (Kasamatsu and Tanaka, 1992). They analysed the yearly change of prey species of common minke whale off Sanriku during 1948 to 1987. Commercial whaling had been made from January to September with peaks from April to June. After 1980, the peak of catch was observed in April. The dominant prey species were krill, Japanese sand lance and *iwashi* (Japanese sardine and/or Japanese anchovy). They pointed out that the yearly change of Japanese sardine in stomach contents were similar to the yearly trend of fisheries catch of Japanese sardine in this area.

The observed maximum stomach contents weight was 102.6 kg (2.0 % of body weight). Our daily estimated prey consumption was from 120 kg to 244 kg (from 3.8 % to 4.8 % of body weight). Common minke whale should take on prey at several times due to meet a demand for their energy requirement in a day. Based on diurnal change in feeding activity of common minke whale in the western North Pacific, Tamura and Fujise (2000c) pointed out that common minke whales feed on prey at several times throughout the day at the surface. Our results supported their consideration.

The seasonal consumption of common minke whales distributed off Sanriku during April and May (60 days) was 834-1,919 tons. The total consumption of Japanese sand lance estimated 683-1,616 tons. Based on results of the sand lance consumption by common minke whales and the degree of overlap between fisheries ground of Japanese sand lance and sighting position of common minke whales, it is conceivable that the possibility with direct interaction between common minke whale and Japanese sand lance fisheries occurs. The fisheries season of Japanese sand lance is from February to May, and common minke whales also feed on Japanese sand lance in the later half of the season. Furthermore, sighting positions of common minke whales were overlapped fisheries ground of Japanese sand lance. The catch quota and season of Japanese sand lance off the Sanriku region (around the Sendai Bay) is regulated by the fisheries conference in order to protect the resources of Japanese sand lance and price control. However common minke whales feed on Japanese sand lance about one third of catch. Therefore, consumption by common minke whales should be taken into account for fishery management of Japanese sand lance off Sanriku region. The ecosystem model (*e.g.* Okamura et al., 2009) will make clear the interaction between minke whales and sand lance.

Furthermore, some fishermen indicate the fishing operation have interfered by common minke whales. Some minke whales attack and feed on the school of sand lance when fishermen attracted fishes around boat, causing dispersion of the schools of Japanese sand lance.

Kushiro region

Kasamatsu and Tanaka (1992) analysed the yearly change of prey species of common minke whale off Kushiro region during 1948 to 1987. Commercial whaling was made from April to October with peaks from July to September. After 1982, two peaks were observed in July and September. The dominant prey species were krill, Japanese sand lance, chub mackerel, *iwashi* (Japanese sardine and/or Japanese anchovy), walleye pollock, Pacific saury and Japanese flying squid. They pointed out that the yearly change of Japanese sardine in the stomach contents were similar to the yearly trend of abundance of Japanese sardine in this area. In the results of JARPN II, the dominant prey

species of common minke whales sampled off Kushiro region from September to October were krill, Japanese anchovy, Pacific saury, walleye pollock and Japanese flying squid. This result was similar to the previous report.

The maximum stomach contents weight was 154.3 kg (2.6 % of body weight). Our daily estimated prey consumption was from 73 kg to 270 kg (from 3.8 % to 4.8 % of body weight). Common minke whale should take on prey at several times due to meet a demand for their energy requirement in a day. Based on diurnal change in feeding activity of common minke whale in the western North Pacific, Tamura and Fujise (2000c) pointed out that common minke whales feed on prey at several times throughout the day at the surface. Our results supported their consideration.

The total consumption of common minke whales distributed off Kushiro during September and October (60 days) was approximately 745–5,190 tons. The prey consumption of economically important Pacific saury, walleye pollock and Japanese common squid by common minke whales were calculated as 39–1,075 tons, 95–2,322 tons and 3–1,753 tons, respectively.

Based on results of the Pacific saury consumption by common minke whales and the degree of overlap between fisheries ground of Pacific saury and sighting position of common minke whales, it is conceivable that the possibility with direct interaction between common minke whale and Pacific saury fisheries occurs. The fisheries season of Pacific saury is from August to October, and common minke whales also feed on Pacific saury in the same season. Tamura and Fujise (2002c) noted that most of the common minke whales sightings in sub-area 7W occurred close to fishing grounds of Pacific saury. This observation suggested the direct interaction between common minke whales and Pacific saury fishery from summer to autumn in the western North Pacific. Therefore, consumption by common minke whales should be taken into account for fishery management of Pacific saury off Kushiro region. Furthermore, some fishermen indicate the fishing operation have interfered by common minke whales. Some minke whales attack and feed on the school of Pacific saury when fishermen attracted fishes around boat, causing dispersion of the schools of Pacific saury.

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Table 1. Sample size of common minke whale off Sanriku and Kushiro regions.

Year	2002	2003	2004	2005	2006	2007
Sanriku	-	50	-	60	60	57
Kushiro	50	-	59	60	35	50

Table 2. Results of caloric value of dominant prey species

Species	Size	Body length	Body weight	**Energy Kcal/kg**
Copepoda (*Neocalanus cristatus*)				**920**
Krill（*Eupahusia pacifica*）				**850**
Sand lance				**1,840**
Japanese anchovy				
	Small	86 mm	7 g	**1,320**
	Large	125 mm	18 g	**1,530**
Pacific saury				
	Small	158 mm	16 g	**1,260**
	Large	300 mm	145 g	**3,140**
Walleye pollock		192 mm	66 g	**1,490**
		430 mm	624 g	**1,480**
Japanese flying squid		206 mm	200 g	**1,580**
Deep-sea squid		6,700 mm	6,930 g	**650**

Table 3. Sexual maturity composition (%) of common minke whales off Sanriku and Kushiro regions.

(IM: Immature male; MM: Mature male; IF: Immature female; MF: Mature female)

Sanriku

	2003	2005	2006	2007
IM	24.5	25.0	23.3	19.6
MM	16.3	13.3	20.0	16.1
IF	40.8	38.3	51.7	51.8
MF	18.4	23.3	5.0	12.5
N	50	60	60	57

Kushiro

Year	2002	2004	2005	2006	2007
IM	32.0	25.4	25.4	36.4	35.4
MM	32.0	54.2	49.2	33.3	29.2
IF	22.0	16.9	25.4	24.2	35.4
MF	14.0	3.4	0.0	6.1	0.0
N	50	59	60	35	50

Table 4. Results of numbers of whales distributed in Sanriku and Kushiro regions

(Ref. Hakamada *et al*., 2009; Table 3)

(IM: Immature male; MM: Mature male; IF: Immature female; MF: Mature female)

Sanriku

Year	Sex maturity	Number
2005	IM	62
	MM	33
	IF	95
	MF	58
	Total	247
2006	IM	29
	MM	25
	IF	64
	MF	6
	Total	123

Kushiro

Year	Sex maturity	Number
2002	IM	192
	MM	192
	IF	132
	MF	84
	Total	601
2004	IM	94
	MM	200
	IF	62
	MF	12
	Total	368
2005	IM	80
	MM	155
	IF	80
	MF	0
	Total	316
2006	IM	88
	MM	80
	IF	58
	MF	15
	Total	241
2007	IM	50
	MM	41
	IF	50
	MF	0
	Total	142

Table 5. Diet composition (*RW*: %) in the stomach contents of common minke whales off Sanriku and Kushiro regions

Sanriku

	2003			2005			2006			2007		
Number	N=50			N=60			N=60			N=57		
	Broken		12	Broken		10	Broken		15	Broken		17
	Empty		0 (0.0%)	Empty		0 (0.0%)	Empty		1 (1.7%)	Empty		0 (0.0%)
Species	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D
Krill	13	37.9	45.13± 40.93	15	5.7	52.39±34.95	1	0.1	1.24	1	1.7	13.01
Anchovy	-	-	-	26	10.1	31.12±28.78	7	18.0	11.67±17.44	-	39.5	13.40±18.80
Sand lance	29	62.1	33.20± 44.76	48	84.2	32.42±32.72	1	81.9	24.46±27.17	2	58.8	12.08±19.15

Kushiro

	2002			2004			2005			2006			2007		
Number	N=50			N=59			N=60			N=35			N=50		
	Broken		3	Broken		1	Broken		5	Broken		1	Broken		13
	Empty		0 (0.0%)	Empty		0 (0.0%)	Empty		0 (0.0%)	Empty		0 (0.0%)	Empty		0 (0.0%)
Species	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D	N	W%	kg±S.D
Krill	4	10.9	42.42±38.61	1	1.9	26.89	17	13.3	22.95±17.34	1	0.5	3.32	5	2.9	9.26±7.01
Anchovy	31	19.0	9.56±9.32	43	53.7	17.80±15.18	30	9.5	9.31±8.56	6	60.6	12.13±14.34	20	46.2	36.92±51.43
Saury	20	16.6	12.96±26.30	23	40.6	25.13±27.29	5	1.2	7.10±9.82	6	7.6	15.67±6.02	9	13.8	24.46±41.74
Walleye pollock	12	19.7	25.58±22.57	4	3.6	12.89±15.61	20	71.5	104.61±220.83	7	25.4	22.56±48.80	15	25.0	26.58±28.04
Japanese flying squid	8	33.8	65.90±50.12	1	0.1	1.58	3	4.5	43.59±71.49	2	5.9	36.42	2	12.1	96.48±135.31
Pacific pomfret	-	-	-	-	-	-	-	-	-	-	-	-	1	0.1	1.24
Salmonids	-	-	-	1	0.2	2.25	-	-	-	-	-	-	-	-	-
Other fish	2	0.1	0.44±0.15	-	-	-	-	-	-	-	-	-	0	-	-

Table 6. Prey composition of common minke whales sampled in JARPN II.

Sanriku

Number of prey species	Prey species	N	%
1	Japanese sand lance	109	63.4
	Krill	10	5.8
	Japanese anchovy	9	5.2
	Total	128	74.4
2	Japanese sand lance+Japanese anchovy	18	10.5
	Japanese sand lance+Krill	2	1.2
	Japanese anchovy+Japanese sand lance	19	11.0
	Krill+Japanese sand lance	5	2.9
	Total	44	25.6
No. whales Observed		172	100.0

Kushiro

Number of prey species	Prey species	N	%
1	Japanese anchovy	99	43.0
	Walleye pollock	21	9.1
	Pacific saury	19	8.3
	Krill	9	3.9
	Japanese neon flying squid	6	2.6
	Total	154	67.0
2	Japanese anchovy+Pacific saury	13	5.7
	Japanese anchovy+Walleye pollock	4	1.7
	Japanese anchovy+Japanese neon flying squid	2	0.9
	Japanese anchovy+Salmonidae	1	0.4
	Walleye pollock+Japanese anchovy	9	3.9
	Walleye pollock+Pacific saury	2	0.9
	Walleye pollock+Krill	2	0.9
	Walleye pollock+Japanese neon flying squid	1	0.4
	Pacific saury+Japanese anchovy	10	4.3
	Pacific saury+Japanese neon flying squid	1	0.4
	Krill+Walleye pollock	6	2.6
	Krill+Japanese anchovy	5	2.2
	Krill+Pacific saury	2	0.9
	Krill+Japanese neon flying squid	1	0.4
	Japanese neon flying squid+Japanese anchovy	3	1.3
	Total	62	27.0
3	Japanese anchovy+Pacific saury+Walleye pollock	1	0.4
	Japanese anchovy+Pacific saury+Japanese neon flying squid	1	0.4
	Walleye pollock+Japanese anchovy+Pacific saury	5	2.2
	Walleye pollock+Krill+Pacific saury	1	0.4
	Walleye pollock+Pacific saury+Other squid	1	0.4
	Pacific saury+Walleye pollock+Japanese anchovy	2	0.9
	Pacific saury+Walleye pollock+Japanese pomfret	1	0.4
	Krill+Japanese anchovy+Walleye pollock	1	0.4
	Krill+Pacific saury+Walleye pollock	1	0.4
	Total	14	6.1
No. whales Observed		230	100.0

Table 7. The daily consumption (kg) n each year and area of common minke whales.

(IM: Immature male; MM: Mature male; IF: Immature female; MF: Mature female)

Sanriku

Month	2003				2005				2006				2007			
Maturity stage	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF
Prey / Consumption (kg)																
Krill	43	72	43	89	5	9	5	11	0.1	0.2	0.1	0.2	2	3	2	3
Anchovy	0	0	0	0	10	16	10	20	17	28	17	35	38	65	39	80
Sand lance	70	118	71	146	79	134	81	166	76	128	77	158	57	96	58	119
Total	113	190	114	236	94	159	96	197	93	156	94	193	97	164	99	203

Kushiro

Month	2002				2004				2005				2006				2007			
Maturity stage	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF	IM	MM	IF	MF
Prey / Consumption (kg)																				
Krill	11	20	10	24	1	3	1	3	16	30	15	36	1	1	0	1	3	3	2	4
Anchovy	18	35	17	42	42	79	39	95	11	21	11	26	61	115	57	139	45	49	26	62
Saury	16	31	15	37	31	60	30	72	1	3	1	3	8	14	7	17	13	15	8	18
Walleye pollock	19	36	18	44	3	5	3	6	84	160	80	193	25	48	24	58	24	27	14	33
Japanese flying squid	33	62	31	75	0	0	0	0	5	10	5	12	6	11	6	14	12	13	7	16
Pacific pomfret	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0.1	0.1
Salmonids	0	0	0	0	0.2	0.3	0.1	0.4	0	0	0	0	0	0	0	0	0	0	0	0
Other fish	0.1	0.2	0.1	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	97	184	92	223	78	147	73	178	118	224	111	270	100	190	95	229	97	107	57	133

Table 8. The prey consumption (tons) by common minke whales off Sanriku and Kushiro regions

Sanriku

Year	2005	2006
Krill	109	1
Anchovy	194	150
Sand lance	1,616	683
Total	1,919	834

Kushiro

Year	2002	2004	2005	2006	2007
Krill	565	50	432	10	22
Anchovy	985	1,422	308	1,217	344
Saury	861	1,075	39	153	103
Walleye pollock	1,021	95	2,322	510	186
Japanese flying squid	1,753	3	146	118	90
Pacific pomfret	0	0	0	0	1
Salmonids	0	5	0	0	0
Other fish	5	0	0	0	0
Total	5,190	2,650	3,247	2,008	745

Table 9. Commercial fish catches and estimated consumption by minke whales of the Japanese sand lance, Pacific saury, walleye pollock and Japanese flying squid

(Ref. Miyagi Prefecture Fisheries Technology Institute, 2008; Hokkaido government, 2008)

Sanriku

Sand lance

Year	Fisheries catch	Consunption by whales	%
2003	6,659	-	-
2004	7,016	-	-
2005	8,623	1,616	18.7
2006	5,552	683	12.3

Kushiro

Pacific saury

Year	Fisheries catch	Consunption by whales	%
2002	55,594	861	1.5
2003	59,984	1,075	1.8
2004	48,403	39	0.1
2005	58,527	153	0.3
2006	61,895	103	0.2

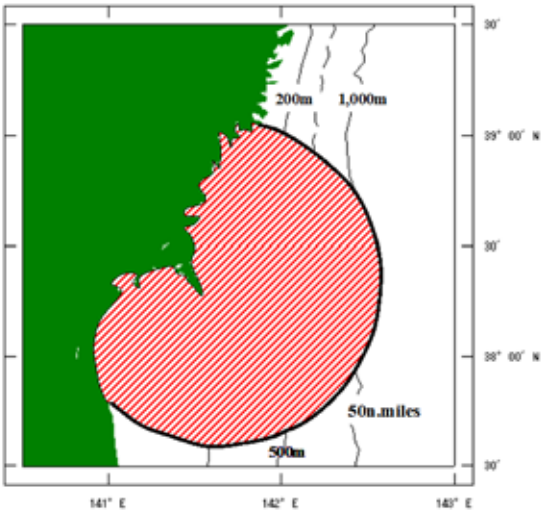
Walleye pollock

Year	Fisheries catch	Consunption by whales	%
2002	52,524	1,021	1.9
2003	75,041	95	0.1
2004	65,186	2,322	3.6
2005	54,628	510	0.9
2006	56,582	186	0.3

Japanese flying squid

Year	Fisheries catch	Consunption by whales	%
2002	1,497	1,753	117.1
2003	3,751	3	0.1
2004	3,721	146	3.9
2005	5,042	118	2.3
2006	2,311	90	3.9

1) Sanriku



2) Kushiro

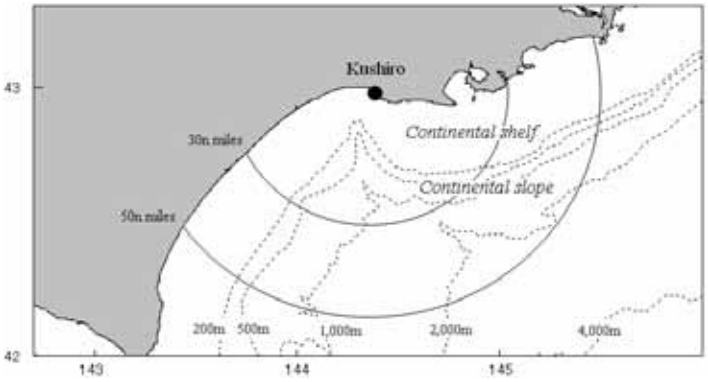


Fig1. Research area off Sanriku and Kushiro regions

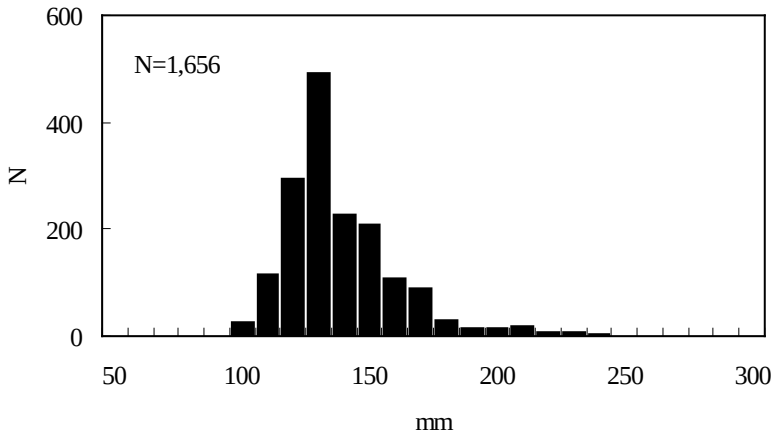


Fig 2-1. The distribution of Japanese sand lance size in the stomach contents of minke whales in Sanrilu region

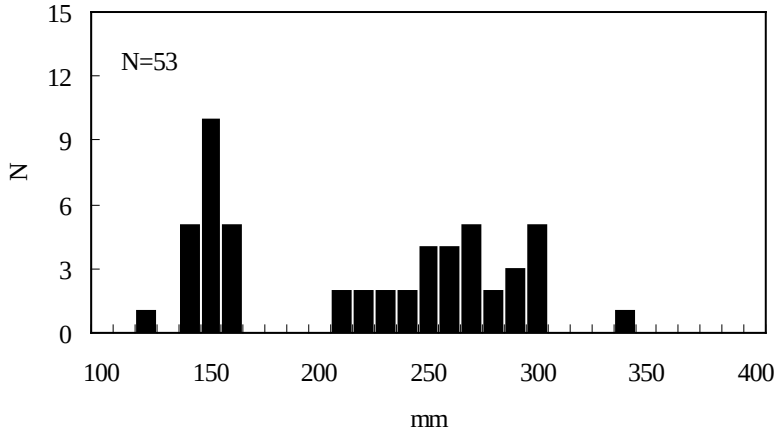


Fig 2-2. The distribution of Pacific saury size in the stomach contents of minke whales in Kushiro region

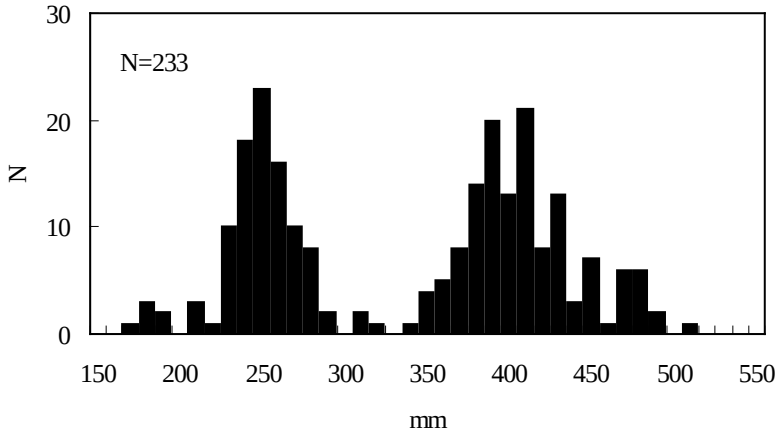


Fig 2-3. The distribution of walleye pollock size in the stomach contents of minke whales in Kushiro region

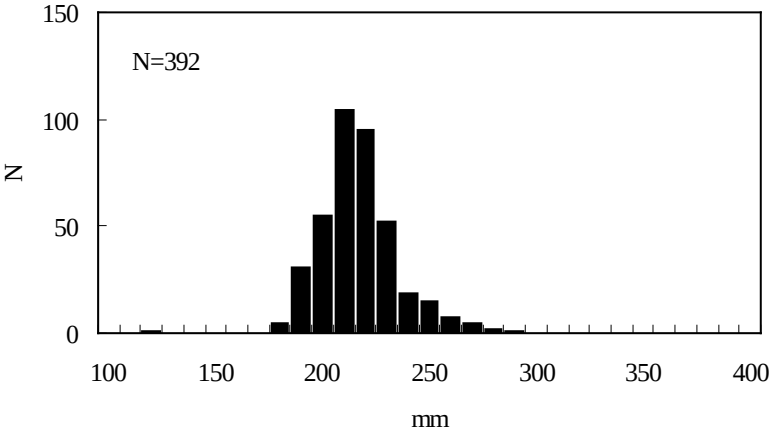


Fig 2-4. The distribution of Japanese flying squid size in the stomach contents of minke whales in Kushiro region