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Geographical and seasonal changes of the prey species of minke whale in the Northwestern Pacific

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The forestomach contents of 498 minke whales *Balaenoptera acutorostrata* sampled in the Northwestern Pacific from May to September through the 1994–1999 JARPN surveys, were analysed. Sixteen prey species consisting of 1 copepod, 4 euphausiids, 1 squid, and 10 fishes were identified. The minke whale in the Northwestern Pacific is a swallowing, feeding-type species. It feeds on swarming zooplankton and schooling fishes, suggesting that minke whales pursue single prey-species aggregations. The results showed geographical and seasonal changes of prey species. On the Pacific side of Japan, Japanese anchovy was the most important prey species in May and June, while Pacific saury was most important in July and August. Walleye pollock was also an important prey species during June and September in coastal waters, over the continental shelf. In the southern Okhotsk Sea krill was the most important prey species in July and August. These changes probably reflect changes in the availability of the prey species in these areas. It would seem that there might be direct competition between minke whales and the fishery for Pacific saury.

Keywords: minke whale, prey species, geographical change, seasonal change, North Pacific.

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Introduction

The 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 other in the Okhotsk Sea–West Pacific (O stock) (IWC, 1983). The abundance of minke whales was estimated to be 19 209 animals with 95% confidence interval (10 069–36 645) in the Okhotsk Sea and 5841 animals with 95% confidence interval (2835–12 032) in the Northwest Pacific during August and September in 1989 and 1990 (Buckland *et al.*, 1992).

In the western North Pacific, minke whales are opportunistic feeders with a broad diet and with flexible feeding habits. According to previous reports they consume several fish species and their prey consumption is huge (Omura and Sakiura, 1956; Tomilin, 1967; Zhongxue *et al.*, 1983; Kasamatsu and Hata, 1985; Kasamatsu and Tanaka, 1992; Tamura *et al.*, 1998). They seem to play an important role in the food web from spring to autumn. To understand their role in the marine ecosystem in Northwest Pacific, it is necessary to obtain more information, both qualitative and quantitative, of their feeding habits. However, there have been few published reports on this topic in the last decade. Furthermore, quantitative data on stomach contents has been lacking.

The "Japanese Whale Research Program under Special Permit in the Western North Pacific" (JARPN) began in 1994 in order to elucidate the stock structure of the western North Pacific minke whale. In 1996, the new objective of studying the feeding ecology was added with data on this subject being gathered from this year.

In this study, the geographical and seasonal changes of prey species and prey size based on the forestomach contents of 498 minke whales collected under JARPN auspices from spring to autumn in the period 1994–1999 were examined.

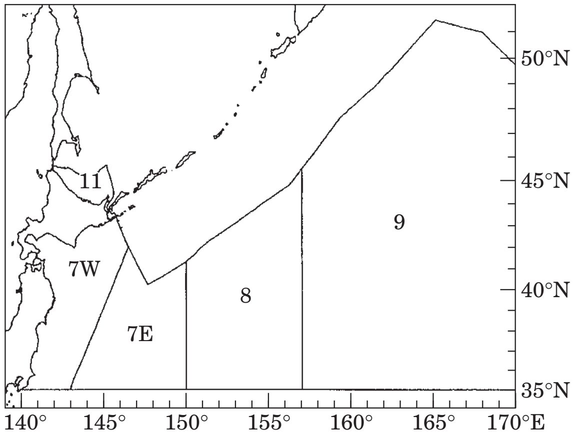

Figure 1. Subareas surveyed by the JARPN cruises between 1994 and 1999. Subareas based on IWC (1994), excluding the EEZ of Russia. Furthermore, subarea 7 was divided into east (7E) and west (7W).

Table 1. Subareas, months and years of surveys and sample size used in this study.

Subarea	Survey month	Year	Sample size
7W	June	1999	50
	August	1996	15
	September	1996	15
7E	May	1998	56
	June	1997	2
	July	1996	1
8	May	1998	8
	June	1998	36
	July	1996, 1997	42
	August	1996	5
9	May	1997	27
	June	1995, 1997	54
	July	1994, 1995	69
	August	1994, 1995	34
	September	1994	4
11	July	1999	50
	August	1996	30
Total			498

Materials and methods

Sampling of whales

The minke whales were sampled in subareas 7, 8, 9, and 11 – excluding the EEZ of foreign countries – which were established by the IWC (IWC, 1994). Furthermore, subarea 7 was divided into east (7E) and west (7W) (Figure 1). Table 1 shows the months, year and number of samples in each subarea. Sampled whales were transported immediately to a research vessel, where biological measurements and sampling was carried out. To randomize the sampling a searching procedure for whales along randomly predetermined transects within each sub area was used (Kato *et al.*, 1989). When a whale was observed during the survey, every effort was made to catch it regardless of problems encountered. The transects were designed in saw-tooth patterns. However, to improve the efficiency of the search operations, a certain degree of freedom allowed the modification of transect lines during the course of operations, depending on factors such as bad weather conditions.

The whales were sampled using one research vessel ('Nisshin Maru') and two or three sighting/sampling vessels ('Kyo Maru No.1', 'Toshi Maru No.25' and 'Toshi Maru No.18' or 'Yushin Maru').

Sampling of stomach contents

Minke whales have a four-chambered stomach system (Hosokawa and Kamiya, 1971; Olsen *et al.*, 1994). Once the whale was on the research base vessel's upper deck the four stomachs were removed within 8 h of capture. Then each stomach content (including and excluding liquid respectively) was weighed to the nearest 0.1 kg. The forestomach content has proved sufficient for the determination of minke whale diet in the Northeast Atlantic because it contains the least digested and most easily identifiable prey remains (Lindstrøm *et al.*, 1997). The prey composition of forestomach and fundus was very similar and therefore this study was based on contents from the forestomach only.

In the 1994 and 1995 JARPN surveys, a sub-sample (3–4 kg) of the content was removed and frozen and/or fixed with 10% formalin water for later analyses. From 1996 onwards, forestomach contents were transferred to a system consisting of three sieves (20 mm, 5 mm, and 1 mm) which is used by Norwegian fisheries' scientists to filter off liquid from the rest of the material (Haug *et al.*, 1995). From the same year also a sub-sample of 3–4 kg that included all undigested fish skulls, free otoliths and squid beaks, was frozen for later analysis in the laboratory.

Of the 498 minke whales sampled 46 stomachs had been destroyed by the harpoon, and their contents were lost whilst a further 26 stomachs were empty. Hence this analysis is based on 426 forestomach contents.

Observation on stomach-contents samples

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

When undigested fish or squid were found, fork-length, mantlelength or the weights were measured to the nearest mm and g, respectively.

The total number of each fish and squid species in the sub-sample was determined by summing the number of undigested fish and squid, undigested skulls and, because, otoliths are paired, half the total number of free otoliths. The total weight by species in the sub-sample was estimated by multiplying the average body weight of undigested specimens by the number of individuals. The total number and weight by species in the forestomach were estimated by using the figures obtained from the sub-sample and the total weight of forestomach contents. The total weight of each zooplankton was estimated by using an assimilation efficiency of 84% (Lockyer, 1981).

Composition of prey species

The compositions of prey species in each area were calculated. Prey species that contributed less than five percent of the total weight of the forestomach contents were omitted from the analysis because the prey was clearly not a target species and their dietary energy was insignificant.

Feeding Indices

The importance of each dominant prey species was evaluated by using the Combined Rank Index (CRI: Pitcher 1981). The CRI was calculated for each month, subarea and year.

First, we calculated the relative frequency of occurrence of each prey species (RF) as follows:

$$RF=(Ni/N_{all}) \times 100 \quad (1)$$

Ni = the number of stomachs containing prey group i
N_{all} = the total number of stomachs analysed.

Then, the relative prey importance by weight of each prey species (RW) was calculated as follows:

$$RW=(W_i/W_{all}) \times 100 \quad (2)$$

W_i = the weight of contents containing prey group i
W_{all} = the total weight of contents analysed.

The CRI was then calculated as follows:

$$CRI = \text{rank of RF} \times \text{rank of RW} \quad (3)$$

Results

Diversity of prey species

A total of sixteen prey species, including 1 copepod, 4 euphausiids, 1 squid, and 10 fishes were identified in the 426 stomachs of minke whales (Table 2). In order to simplify the comparison of feeding indices the prey species were divided into the following prey groups: copepods, krill, squid, Japanese anchovy, Japanese pilchard, Pacific saury, walleye pollock, Chub mackerel, Japanese pomfret, Salmonidae and other fishes.

Table 2. Prey species found in the stomachs of minke whales sampled by the JARPN surveys between 1994 and 1999.

Copepods		*Neocalanus cristatus*
Krill		*Euphausia pacifica*
		Thysanoessa inermis
		T. inspinata
		T. longipes
Squid	Japanese common squid	*Todarodes pacificus*
Pisces	Pacific saury	*Cololabis saira*
	Japanese anchovy	*Engraulis japonicus*
	Japanese pilchard	*Sardinops melanostictus*
	Walleye pollock	*Theragra chalcogramma*
	Chub mackerel	*Scomber japonicus*
	Japanese pomfret	*Brama japonica*
	Pink salmon	*Oncorhynchus gorbuscha*
	Coho salmon	*O. kisutch*
	Daggertooth	*Anotopterus pharao*
	Japanese sand lance	*Ammodytes hexapterus*

Composition of prey species

Most minke whales (90.4%) had fed upon one single prey species, 8.5% had fed upon two species and only 1.2% had more than two prey species in the forestomach (Table 3).

Geographical and seasonal changes in dominant prey species in the forestomach

Pacific side of Japan

In subareas 7, 8, and 9 Japanese anchovy was the dominant prey species, occurring in 43–100% of the stomach examined and composing 43–97% of the total weight ingested in May and June (Table 4A and 4B). In May minke whales consumed Japanese anchovy in the southern part of the research area (35°N–40°N) (Figure 2A), while in June minke whales consumed this species in the southern and middle part of the research area (35°N–45°N) (Figure 2B).

In July and August Pacific saury was the dominant prey species, occurring in 43–100% of the stomach contents examined and composing 43–94% of the total weight ingested (Table 4C and 4D). In July, minke whales consumed this species in the northern and middle part of the research area (Figure 2C). In August, they consumed this species mainly in the northern and middle part of the research area (Figure 2D).

In September krill was the dominant prey species, occurring in 50–54% of the stomach contents examined and composing 48–50% of the total weight ingested

Table 3. Composition of prey species found in the stomachs of 426 minke whales sampled by JARPN surveys between 1994 and 1999.

Number of prey species	Prey species	7W		7E		8		9		11		Total	
		N	%	N	%	N	%	N	%	N	%	N	%
1	Copepoda								1	0.6		1	0.2
	Krill	7	9.2	1	2.1	1	1.3	7	4.3	57	91.9	73	17.1
	Japanese anchovy	44	57.9	42	89.4	34	44.2	61	37.2	5	8.1	186	43.7
	Pacific saury	11	14.47			32	41.6	70	42.7			113	36.5
	Walleye pollock	8	10.5									8	1.9
	Japanese pomfret							1	0.6			1	0.2
	Salmons			1	2.1			1	0.6			2	0.5
	Barracudas							1	0.6			1	0.2
	Total	70	92.1	44	93.6	67	87.0	142	86.6	62	100.0	385	90.4
2	Krill+Japanese anchovy			1	2.1							1	0.2
	Krill+Pacific saury	1	1.3	1	2.1	1	1.3	6	3.7			9	2.1
	Krill+Walleye pollock	1	1.3									1	0.2
	Krill+Salmons							1	0.6			1	0.2
	Krill+Barracudas							1	0.6			1	0.2
	Japanese anchovy+Japanese pilchard							4	2.4			4	0.9
	Japanese anchovy+Pacific saury					2	2.6	2	1.2			4	0.9
	Japanese anchovy+Walleye pollock	1	1.3									1	0.2
	Japanese anchovy+Salmons			1	2.1	2	2.6					3	0.7
	Chub mackerel+Japanese pilchard					1	1.3					1	0.2
	Pacific saury+Japanese pomfret	1	1.3					1	0.6			2	0.5
	Pacific saury+Walleye pollock											0	0.0
	Pacific saury+Chub mackerel	1	1.3									1	0.2
	Pacific saury+Salmons					2	2.6	3	1.8			5	1.2
	Pacific saury+Barracudas							1	0.6			1	0.2
	Pacific saury+Squids					1	1.3					1	0.2
	Total	5	6.6	3	6.4	9	11.7	19	11.6	0	0.0	36	8.5
3	Krill+Pacific saury+Salmons							2	1.2			2	0.5
	Krill+Pacific saury+Squids	1	1.3									1	0.2
	Japanese anchovy+Pacific saury+Squids					1	1.3					1	0.2
	Pacific saury+Japanese pomfret+Salmons							1	0.6			1	0.2
	Total	1	1.3	0	0.0	1	1.3	3	1.8	0	0.0	5	1.2
	No. whales observed76		100.0	47	100.0	77	100.0	164	100.0	62	100.0	426	100.0

Table 4. Geographical and temporal changes in stomach contents of 364 minke whales sampled by JARPN surveys between 1994 and 1999 in the Pacific side of Japan (subareas 7, 8 and 9).

	% Occurrence				% Weight ingested				CRI index			
Prey species (Area / Year)	7W 1998	7E 1998	8 1998	9 1997	7W 1998	7E 1998	8 1998	9 1997	7W 1998	7E 1998	8 1998	9 1997
A. May												
Euphausiacea				4.3				4.8				4
Pisces												
Japanese anchovy		97.7	100.0	95.7		97.0	96.8	91.2		1	1	1
Pacific saury				4.3				4.0				6
Salmonidae		4.5	12.5			3.0	3.2			4	4	
Other fishes												
No. whales observed		44	8	23		44	8	23		44	8	23

	% Occurrence					% Weight ingested					CRI index				
Area	7W	7E	8	9		7W	7E	8	9		7W	7E	8	9	
Prey species (Year)	1999	1997	1998	1995	1997	1999	1997	1998	1995	1997	1999	1997	1998	1995	1997
B. June															
Euphausiacea		100.0	3.7	14.3			55.5	3.7	8.7			1	4	12	
Pisces															
Japanese anchovy	90.0	50.0	96.3	42.9	90.9	89.6	44.5	91.8	42.9	90.9	1	4	1	1	1
Pacific saury			3.7	35.7	9.1			2.9	35.7	9.1			6	4	4
Walleye pollock	12.0					10.4					4				
Salmonidae			3.7	14.3				1.6	12.7				8	9	
No. whales observed	50	2	27	14	33	50	2	27	14	33	50	2	27	14	33

	% Occurrence						% Weight ingested						CRI index					
Area	7W	7E	8		9		7W	7E	8		9		7W	7E	8		9	
Prey species (Year)		1996	1996	1997	1994	1995		1996	1996	1997	1994	1995		1996	1996	1997	1994	1995
C. July																		
Copepoda						0.01						0.01						
Euphausiacea		100.0	10.0			13.0		12.5	8.7			6.0		2	9			4
Cephalopoda																		
Japanese flying squid				7.4						2.2						4		
Pisces																		
Japanese anchovy			20.0	7.4	57.1	7.4			20.0	2.3	42.5	5.1			4	4	2	12
Japanese pilchard					57.1						14.7						3	
Pacific saury		100.0	80.0	100.0	42.9	92.6		87.5	71.3	94.3	42.9	85.0		1	1	1	2	1
Japanese pomfret						1.9						0.4						36
Salmonidae				7.4		9.3				1.2		3.1				6		12
Other fishes						3.7						0.5						25
No. whales observed		1	10	27	7	54		1	10	27	7	54		1	10	27	7	54

Prey species	Area / Year	% Occurrence					% Weight ingested					CRI index				
	Area	7W	7E	8	9		7W	7E	8	9		7W	7E	8	9	
	Year	1996	1996	1996	1994	1995	1996	1996	1996	1994	1995	1996	1996	1996	1994	1995
D. August																
Copepoda						10.0					0.3					12
Euphausiacea		23.1			11.1	10.0	21.1			11.1	10.0	4			4	4
Cephalopoda																
Japanese flying squid		15.4					1.6					12				
Pisces																
Japanese anchovy		7.7		20.0	11.1	5.0	0.7		20.0	11.1	5.0	20		4	4	9
Japanese pilchard				20.0					3.8					8		
Pacific saury		76.9		60.0	77.8	75.0	68.3		60.0	77.8	74.4	1		1	1	1
Walleye pollock		7.7					7.7					12				
Chub mackerel		7.7		20.0			0.6		16.2			24		6		
Japanese pomfret						5.0					5.0					9
Other fishes						5.0					5.0					9
No. whales observed		13		5	9	20	13		5	9	20	13		5	9	20

Prey species	Area / Year	% Occurrence				% Weight ingested				CRI index			
	Area	7W	7E		9	7W	7E		9	7W	7E		9
	Year	1996	1996	8	1994	1996	1996	8	1994	1996	1996	8	1994
E. September													
Euphausiacea		53.8			50.0	48.0			50.0	1			1
Pisces													
Pacific saury		38.5			25.0	32.9			25.0	4			4
Walleye pollock		23.1				19.1				9			
Japanese pomfret					25.0				25.0				4
No. whales observed		13			4	13		4	13			4	

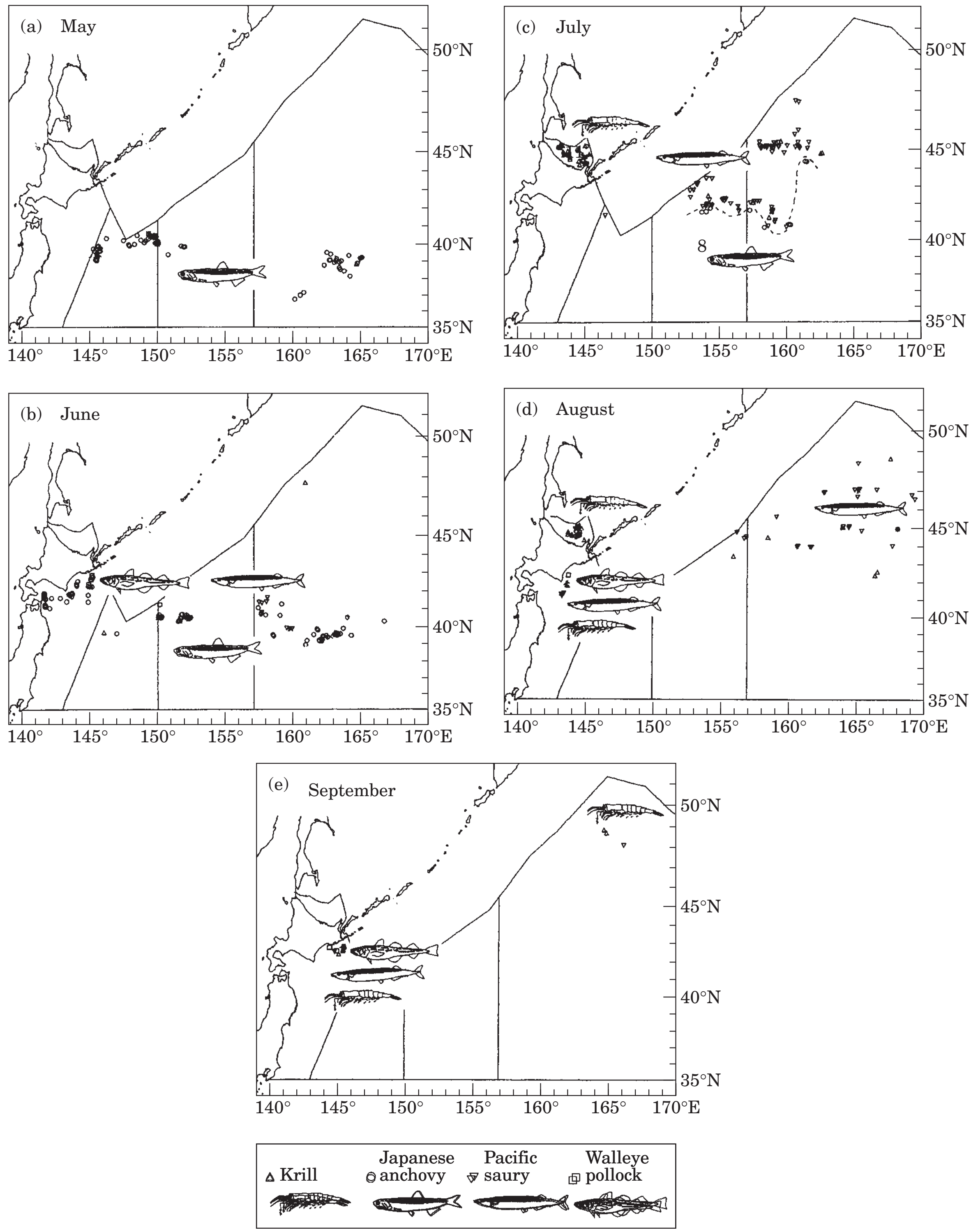

Figure 2. Temporal distribution of minke whales sampled and its dominant prey species.

Table 5. Temporal changes in the stomach contents of 62 minke whales sampled by JARPN surveys in 1996 and 1999 in the southern part of Okhotsk Sea (subarea 11).

Prey species	% Occurrence	% Weight ingested	CRI index
A. July (1999)			
Euphausiacea	87.5	90.0	1
Pisces			
Japanese anchovy	12.5	10.0	4
No. whales observed	40	40	40
B. August (1996)			
Copepoda	0.09	0.01	4
Euphausiacea	100.0	100.0	1
No. whales observed	22	22	22

(Table 4E). Minke whales consumed this species in the northern and middle part of the research area (Figure 2E).

Based on CRI value, the dominant prey species were Japanese anchovy during May and June and Pacific saury during July and August in subareas 7, 8, and 9. Krill was the dominant prey species in subareas 7W and 9 in September (Table 4).

Southern Okhotsk Sea

In subarea 11 krill was the dominant prey species, occurring in 88–100% of the stomach contents examined and composing 90–100% of the total weight ingested. In July minke whales consumed krill and Japanese anchovy while in August they consumed krill only (Figure 2D). Based on CRI value, krill were the dominant prey species in July and August (Table 5A and 5B).

Forklength frequency of dominant fishes ingested by minke whales

The forklength of Japanese anchovy ingested by minke whales ranged from 72 to 142 mm with a single mode at 120 mm (Figure 3A), except in June in subarea 9 and in July in subarea 8.

The forklength of Pacific saury ranged from 149 to 330 mm in subarea 9 and from 160 to 340 mm in subareas 7 and 8. There was a tendency towards finding larger Pacific saury in the offshore subarea (subarea 9) as compared to inshore subareas (subareas 7 and 8) (Figure 3B).

The forklength of walleye pollock in June ranged from 310 to 412 mm with a single mode at 371 mm and in September ranged from 360 to 530 mm with a mode at 437 mm (Figure 3C).

Discussion

Prey species and feeding type

The prey species of minke whales in the western North Pacific and southern Okhotsk Sea during May and September from 1994 to 1999 comprised various pelagic prey species of zooplankton, squid and fishes and varied both geographically and temporally. In the Northern Hemisphere, minke whales consume various pelagic prey species of zooplankton, squid and fishes (Kasamatsu and Tanaka, 1992; Haug *et al.*, 1995, 1996; Tamura, 1998; Tamura *et al.*, 1998), while in the Southern Hemisphere they consume krill (*Euphausia superba*) (Ichii and Kato, 1991; Tamura, 1998). We confirmed that minke whales in the western North Pacific are euryphagous, similar to those in Northeast Atlantic and unlike the stenophagous type found in the Antarctic.

Generally, the baleen whales are grouped into two types by their feeding behaviour, swallowing and skimming (Nemoto, 1959). The former is the group of fin whales, blue whale and humpback whale and the latter is the group of the right whale. Most minke whales had fed upon one single prey species. In each subarea only a few whales had two prey species or more in their stomachs. Judging from these results, minke whale in the western North Pacific is also confirmed to be of the swallowing type. They feed on swarming zooplankton and schooling fish, indicating an ability to pursue single-prey species aggregations.

Geographical and seasonal changes in prey species

On the Pacific side of Japan the dominant prey species was Japanese anchovy during May and June, Pacific saury during July and August and krill in September. In the southern Okhotsk Sea, krill was the dominant prey species in July and August.

In the daytime, Pacific saury is mainly distributed at 10 to 15 m depths where it feeds on copepods and krill (Hotta and Odate, 1956; Wada and Kitakata, 1982). Japanese anchovy is also distributed shallower than 30 m depth, where it feeds on copepods (Kondo, 1969). These two fishes are distributed widely in temperate waters of the western North Pacific. Pacific saury and Japanese anchovy migrate to the area to feed copepod and krill from June through September (Kondo, 1969; Odate, 1977). Minke whales might feed on those at the surface during their seasonal migration to high latitudes. Differences in the CRI between Pacific saury and Japanese anchovy might reflect the local changes in the relative abundance of these species in the area.

In subarea 7W walleye pollock was also an important prey species during June and September. Walleye pollock is separated into surface groups (coastal waters, over continental shelf) and deeper water groups (100–300 m) after spawning (Maeda *et al.*, 1988). Minke whales probably feed on the surface groups because they are important prey species in coastal waters over the continental shelf.

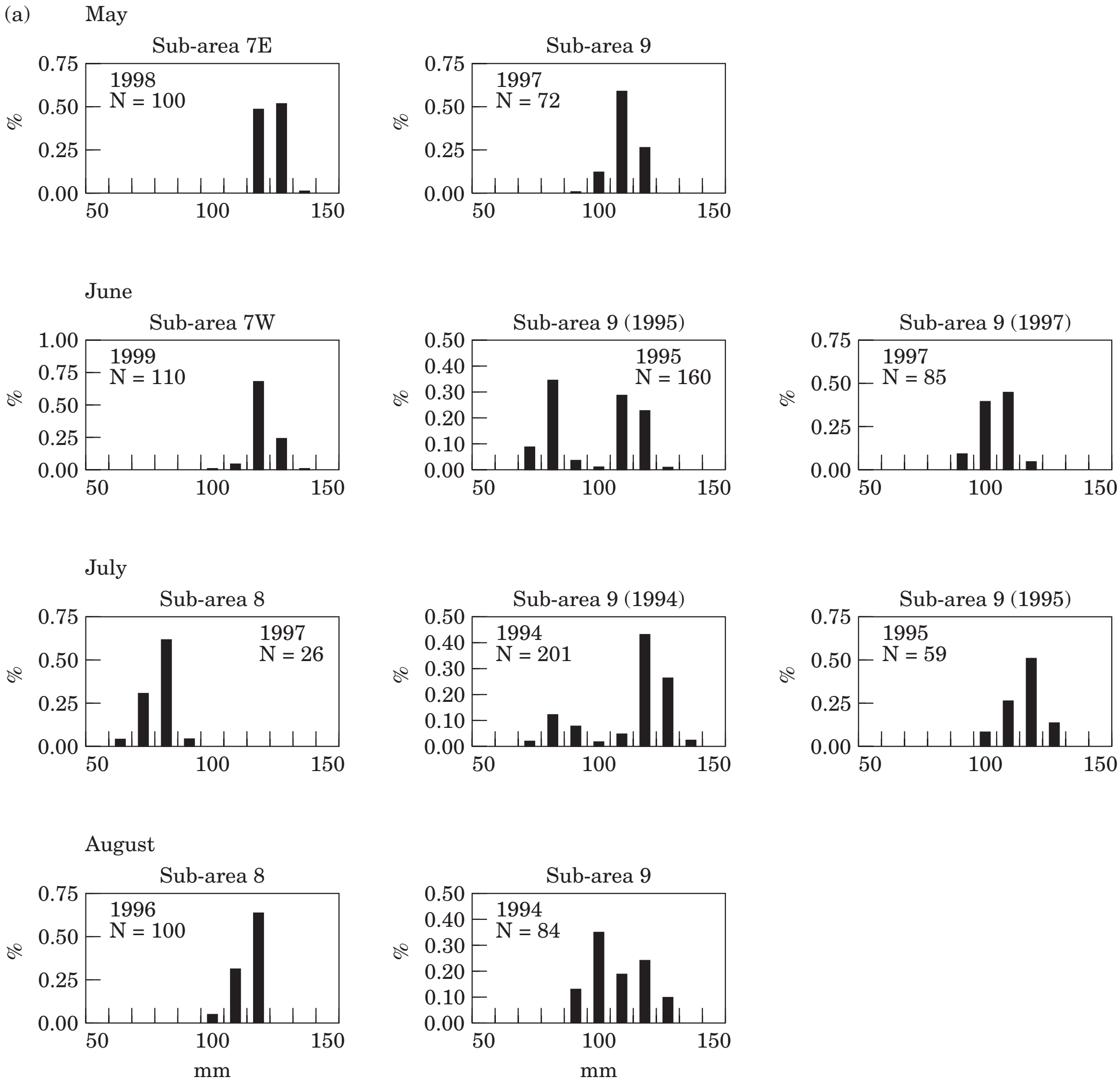

Figure 3. (a).

Unfortunately, our results are insufficient to clarify the feeding ecology of the western North Pacific minke whales because the research areas did not fully cover their distribution of in summer. In the northern and middle Okhotsk Sea (subarea 12), in particular, adult females are found but their prey species are still unknown. More surveys are needed in this area.

Furthermore, our sampling "seasons" did not fully cover the distribution because of the lack of availability of the research fleet. Minke whales in the Northwestern Pacific feed on prey from March to October (Kasamatsu and Tanaka, 1992). In addition, many balaenopterid whales such as fin whales, humpback whales have a cycle of feeding and breeding. In the North Atlantic, the feeding periods of fin whales and minke whales are from spring to autumn (Folkow *et al.*, 2000). Further research is needed to cover the spring to autumn period in the North Pacific.

Yearly changes of prey species

Kasamatsu and Hata (1985) reported that Chub mackerel was the most important prey species of minke whales in the Western Pacific (northern part of subarea 8) in August, and walleye pollock was the most important one for minke whales in east Sakhalin (part of subarea 12) between June and August from test whaling between 1973 and 1975. Kasamatsu and Tanaka (1992) examined annual changes in prey species based on catch

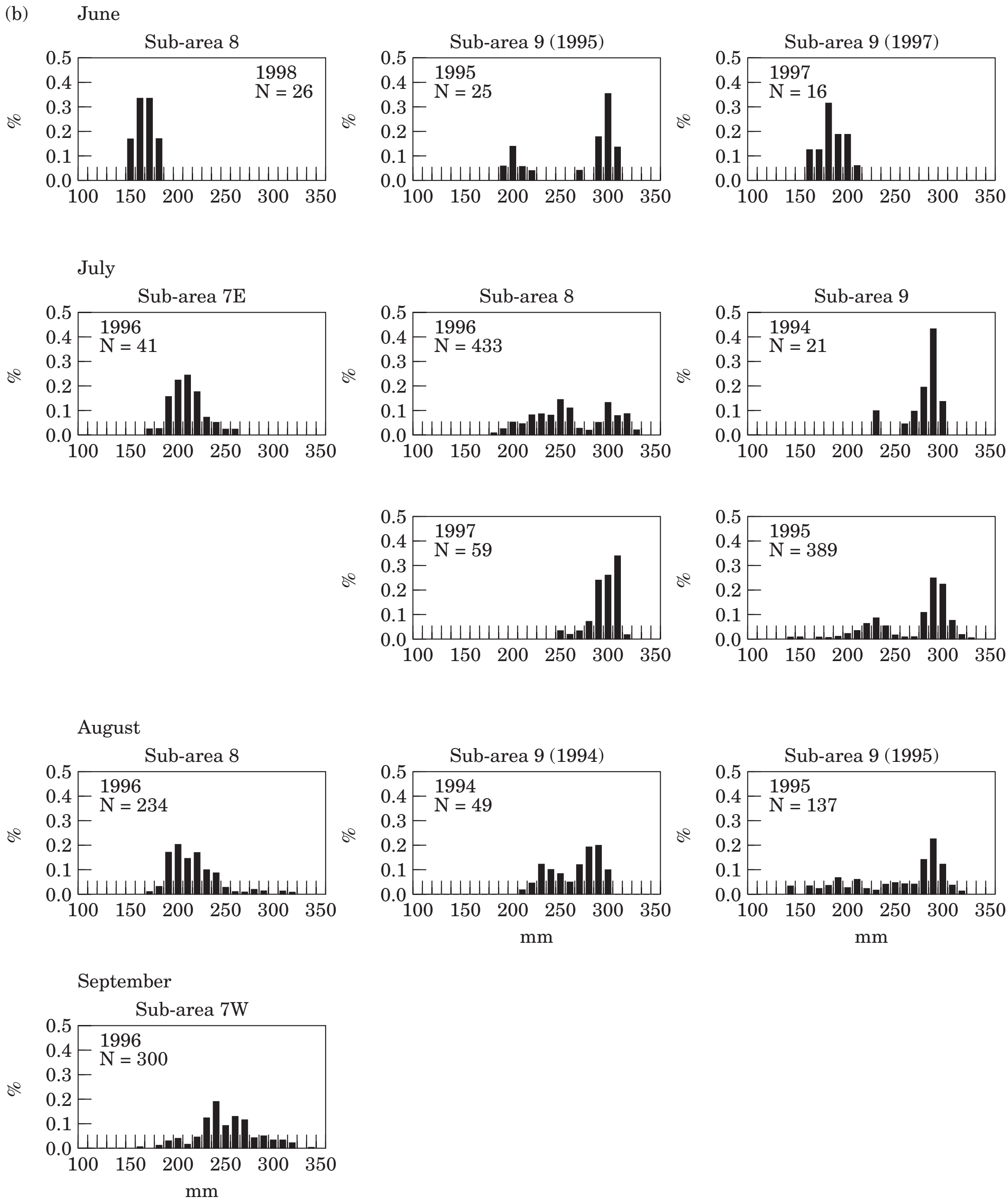

Figure 3. (b).

records of small operations in the seven whaling grounds off Japan from 1948 to 1987. On the Pacific coast of Hokkaido (part of subarea 7W) from April to October, prey species recorded were krill, squid, Japanese pilchard, Japanese anchovy, Chub mackerel, walleye pollock, cod, sand lance, Pacific saury etc. They noted that the change of prey of minke whales from Chub mackerel to Japanese pilchard in 1977 corresponded with a change of the dominant species taken by the commercial fisheries in the same area in 1976. They also reported that krill was the dominant prey species from 1964 to 1987 in the Okhotsk Sea.

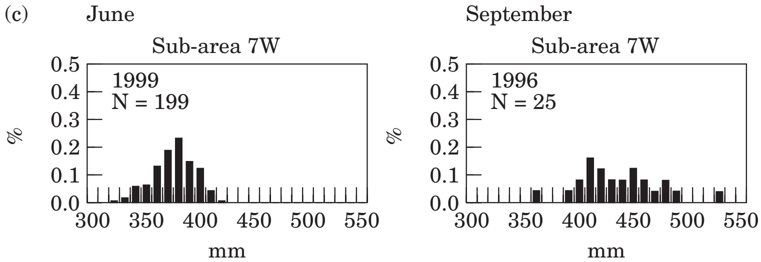

Figure 3. (c).

Figure 3. Forklength frequency of (a) Japanese anchovy, (b) Pacific saury and (c) walleye pollock consumed by minke whales in the western North Pacific.

The yearly change of prey species in subarea 7W (Pacific coast of Hokkaido) was examined also. Figure 4 shows the relative frequency of occurrence of each dominant prey species and the catch data for Japanese pilchard, Chub mackerel and Pacific saury. The change of prey species of minke whales from Chub mackerel to Japanese pilchard in 1977, from Japanese pilchard to Pacific saury in 1996 corresponded with a change of the dominant species taken by commercial fisheries in the same area in 1976, 1996, respectively.

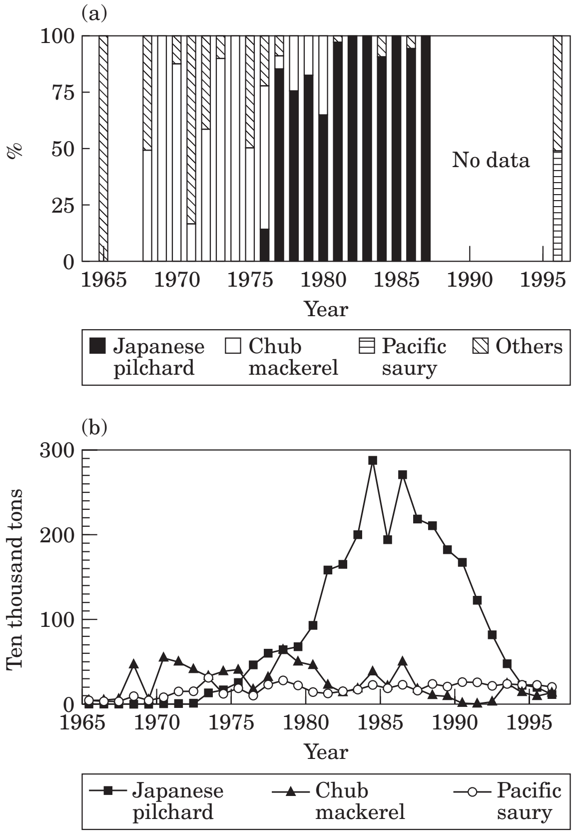

Figure 4. The annual change of relative frequency of occurrence of each dominant prey species consumed by minke whale in subarea 7W (a) and the commercial catch on the Pacific side (b). (The Ministry of Agriculture, Forestry and Fisheries of Japan, 1967–1999; Kasamatsu and Tanaka, 1992; this study).

Because it is reasonable to assume that minke whales do not have a strong preference for a particular prey species (Jonsgård, 1982; Kasamatsu and Tanaka, 1992), changes in prey composition probably reflect changes in the abundance of available prey species. Unfortunately, knowledge of the historical change of abundance of these prey species in the western North Pacific and Okhotsk Sea is insufficient to examine this relationship. The length distributions indicate that minke whales fed primarily on the adult stage of Japanese anchovy (Kondo, 1969), Pacific saury (Odate, 1977) and walleye pollock (Maeda *et al.*, 1972). These fish support important commercial fisheries.

Competition between minke whales and fisheries

In recent years increased attention has been paid to interactions between commercial fisheries and whales. For example, consumption of Atlantic herring *Clupea harengus* by minke whales is estimated to be 633 000 tons per year in a part of the Northeast Atlantic. This is more than half the total Norwegian catch of herring (Folkow *et al.*, 2000).

Figure 5 shows the fishing grounds of Pacific saury and the positions of minke whales sightings in subarea 7W in the survey conducted between 24 August and 5 September 1996 (Fujise *et al.*, 1997). Most sightings occurred close to the fishing grounds. This observation suggests a relationship between minke whales and Pacific saury from summer to autumn in the western North Pacific.

Unfortunately, knowledge of the abundance of these prey species and minke whales in the western North Pacific and southern Okhotsk Sea from spring to autumn is insufficient to examine this relationship. Therefore, more data are urgently needed on seasonal, local and annual variations in both the prey and minke whales before conclusions can be drawn with regard to

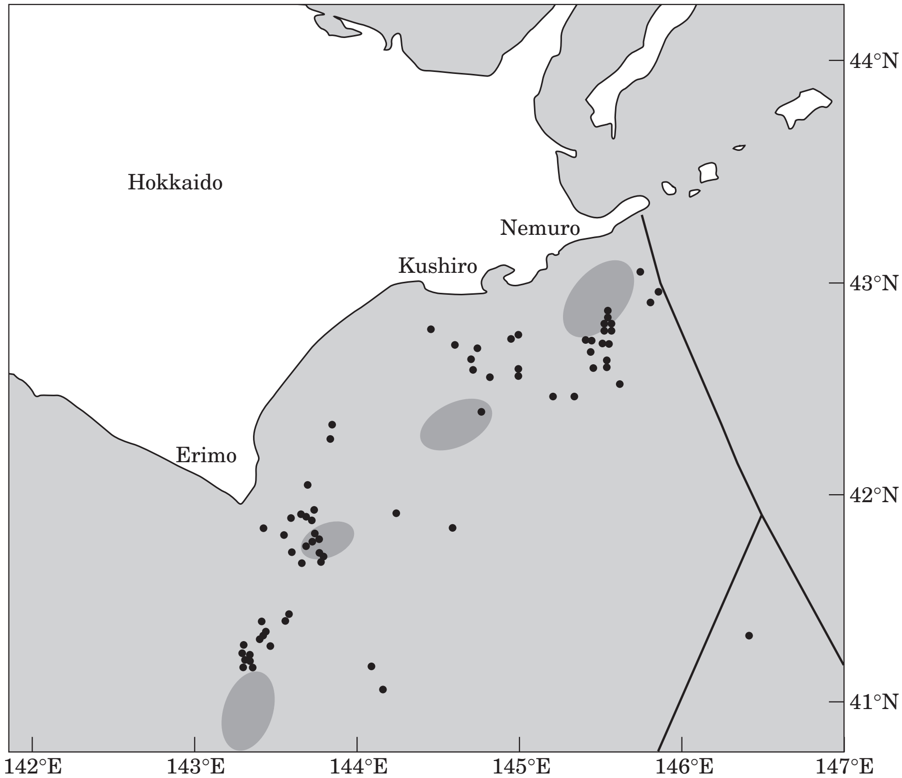

Figure 5. The relationship between minke whale sightings (dot) and the fishing grounds (shaded areas) of Pacific saury in subarea 7W during 22 July and 8 September 1996. The information was obtained from telexes 27–33 relating to the fishing grounds off the Pacific coast of eastern Hokkaido supplied to the Fishing Information Service Centre in Japan (redrawn from Fujise *et al.*, 1997).

their role in the marine ecosystems of the Northwestern Pacific.

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