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

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ABSTRACT

The forestomach contents of 498 minke whales *Balaenoptera acutorostrata* sampled in the western North Pacific from May to September through 1994 - 1999 JARPN surveys, were analyzed. Sixteen prey species consisting of 1 copepod, 4 euphausiids, 1 squid and 10 fishes were identified. We confirmed that the western North Pacific minke whale is a swallowing feeding type species. They feed on swarming zooplankton and schooling fishes, suggesting that minke whales pursue single prey species aggregations. Results showed geographical and seasonal changes of prey species of minke whales. In the Pacific side, Japanese anchovy was the most important prey species in May and June, while Pacific saury was the most important one in July and August. Krill was the most important prey species in September. 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 in the prey species of minke whales probably reflect changes in the availability of prey species in these areas.

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 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 minke whales are opportunistic feeders with a broad diet and with flexible feeding habits. According previous reports, they consume several fish species which are important for Japanese commercial fisheries (Kasamatsu and Hata, 1985; Kasamatsu and Tanaka, 1992; Tamura *et al.*, 1998). In recent years, increased attention has been paid to the interactions between commercial fisheries and whales. Between 1992 and 1994, a scientific whaling program was conducted by Norway to assess the predatory role of Northeast Atlantic minke whales and to address questions concerning its feeding ecology (Haug *et al.*, 1995, 1996). It is necessary to obtain more information on minke whale food habit both qualitative and quantitative.

In this study, we examined geographical and seasonal changes of prey species and prey size based on the forestomach contents of 498 minke whales collected by JARPN surveys from spring to autumn between 1994 and 1999. This paper improves our knowledge of the prey species of minke whale in this region.

MATERIALS AND METHODS

Research area, year and sample size

The research area of the JARPN was a part of sub-areas 7, 8, 9 and 11 which were established by the IWC/SC (IWC, 1994), excluding the EEZ of Russia. Furthermore, sub-area 7 was divided into east (7E) and west (7W) (Fig. 1). The survey months, years and sample size in each sub-area are shown in Table 1. A total of 498 minke whales was examined in this study.

Sampling of stomach contents of minke whales

Minke whales have four chambered stomach system (Hosokawa and Kamiya, 1971; Olsen *et al.*, 1994). The forestomach contents have proved sufficient for determination of the minke whale diet in the Northeast Atlantic (Lindstrøm *et al.*, 1997). The prey composition of prey species between forestomach and fundus were very similar in this study. Therefore, this study was based on contents from forestomach.

The forestomach contents were removed on the ship's flensing deck within eight hours after capture. Then, forestomach contents were weighed to the nearest 0.1 kg.

In the 1994 and 1995 JARPN surveys, a sub-sample (3-4 kg) of forestomach contents was removed and frozen and/or fixed with 10 % formalin water for later analyses. From the 1996 JARPN survey, forestomach 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). Apart the undigested prey, 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

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, 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 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.

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 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

Compositions of prey species were calculated in each area. Prey species that contributed less than five percent of the total weight of the forestomach contents were omitted from the analyses.

Feeding Indices

The importance of each dominant prey species was evaluated by using the Combined Rank Index (*CRI*: Pitcher 1981).

In order to simplify the comparison of feeding indices, prey species were divided into the following prey groups: copepods (*Calanus* spp.), krill (*Euphausia pacifica*, *Thysanoessa longipes*, *T. inermis*, *T. inspinata*), Japanese flying squid (*Todarodes pacificus*), Japanese anchovy (*Engraulis japonicus*), Japanese pilchard (*Sardinops melanostictus*), Pacific saury (*Cololabis saira*), walleye pollock (*Theragra chalcogramma*), Chub mackerel (*Scomber japonicus*), Japanese pomfret (*Brama japonica*), Salmonidae and other fishes. The *CRI* was calculated in each month, area and year.

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

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

Ni = the number of stomachs containing prey group i

N_{all} = the total number of stomachs analyzed.

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

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

W_i = the weight of contents containing prey group i

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

The *CRI* was then calculated as follows:

CRI = rank of RF × rank of RW (3)

RESULTS

Numbers of forestomach examined

Forestomach of 498 minke whales sampled from 1994 to 1999 by JARPN surveys, were examined. Of them, 46 stomachs had been destroyed by the harpoon, and their contents were lost. Also, 26 of the 498 minke whales sampled, the stomachs were empty. We analyzed 426 forestomach contents of minke whales.

Diversity of prey species

A total of sixteen prey species, including 1 copepods, 4 euphausiids, 1 squid and 10 fishes were identified in the 426 stomachs of minke whales (Table 2).

Composition of prey species

Most minke whales (90.4 %) had fed upon one single prey species. A 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 sub-areas 7, 8 and 9 Japanese anchovy was the dominant prey species, occurring in 42.9 – 100.0 % of the stomach examined and composing 42.9 – 97.0 % 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 º – 40 N º)(Fig. 2A), while in June, minke whales consumed this species in the southern and middle part of the research area (35 N º – 45 N º) (Fig. 2B).

In July and August Pacific saury was the dominant prey species, occurring in 42.9 – 100.0 % of the stomach contents examined and composing 42.9 – 94.3 % 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 (Fig. 2C). In August minke whales consumed this species mainly in the northern and middle part of the research area (Fig. 2D).

In September krill was the dominant prey species, occurring in 50.0 – 53.8 % of the stomach contents examined and composing 48.0 – 50.0 % of the total weight ingested (Table 4E). Minke whales consumed this species in the northern and middle part of the research area (Fig. 2E).

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

Southern Okhotsk Sea

In sub-area 11 krill was the dominant prey species, occurring in 87.5 – 100.0 % of the stomach contents examined and composing 90.0 – 100.0 % of the total weight ingested. In July minke whales consumed krill and Japanese anchovy. On the other hand, in August, minke whales consumed krill (Fig. 2D). Based on *CRI* value, krill were the dominant prey species in July and August (Table 5A and 5B).

Fork length frequency of dominant fishes ingested by minke whales

Japanese anchovy

The fork length of Japanese anchovy ingested by minke whales ranged from 72 to 142 mm with a single mode at 120 mm (Fig. 3A), except June in sub-area 9 and July in sub-area 8.

Pacific saury

The fork length of Pacific saury ingested by minke whales ranged from 149 to 330 mm in sub-area 9. Minke whales fed on fish ranging from 160 to 340 mm in sub-areas 7 and 8. There was a tendency towards to find larger Pacific saury in the offshore sub-area (sub-area 9) as compared to inshore sub-areas (sub-areas 7 and 8) (Fig. 3B).

Walleye pollock

The fork length of walleye pollock ingested by minke whales in June ranged from 310 to 412 mm with a single mode at 371 mm. On the other hand, the fork length of walleye pollock ingested by minke whales in September ranged from 360 to 530 mm with a mode at 437 mm (Fig. 3C).

DISCUSSION

Prey species and feeding type

In this study we found that the prey species of minke whales in the western North Pacific and southern Okhotsk Sea during May and September from 1994 to 1999, were occupied various pelagic prey species of zooplankton, squid and fishes. Prey species of minke whales varied both geographically and temporally. In the Northern Hemisphere, minke whales consumed various pelagic prey species of zooplankton, squid and fishes (Kasamatsu and Tanaka, 1992; Haug *et al.*, 1995, 1996; Tamura, 1998; Tamura *et al.*, 1998). On the other hand, in the Southern Hemisphere minke whales consumed 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, but unlike the stenophagous in the Antarctic.

Generally the baleen whales are grouped into two types on the feeding behavior, 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 right whale. In this study, most minke whales had fed upon one single prey species. Only a few whales had more than two prey species in each sub-area. 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 of the minke whales to pursue single prey species aggregations.

Geographical and seasonal changes of prey species

In 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). At the same time, 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 this research area to feed copepod and krill from June through September (Kondo, 1969; Odate, 1977). Minke whales probably feed on those at the surface during their seasonal migration to high latitude. Differences in the *CRI* between Pacific saury and Japanese anchovy might reflect to local changes in the relative abundance of these species in the area.

In sub-area 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 at the surface groups. They are important prey species for minke whale in coastal waters, over the continental shelf.

Yearly changes of prey species

Kasamatsu and Hata (1985) reported that Chub mackerel was the most important prey species of minke whales in western Pacific (a part of sub-area 8) in August, and walleye pollock was the most important one for minke whales in east Sakhalin (a part of sub-area 12) between June and August from 1973 to 1975 data. Kasamatsu and Tanaka (1992) examined annual changes of prey species in the seven whaling grounds off Japan, from 1948 to 1987 data. In Pacific coast of Hokkaido (a part of sub-area 7W) from April to October, prey species recorded were krill, squid, Japanese pilchard, Japanese anchovy, Chub mackerel, walleye pollock, cod, sand lance, Pacific saury and so on. 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 commercial fisheries in the same area in 1976. On the other hand, Kasamatsu and Tanaka (1992) reported krill was dominant prey species from 1964 to 1987 in the Okhotsk Sea.

In addition, we examined the yearly change of prey species of minke whales in sub-area 7W. Fig. 4 shows the relative frequency of occurrence of each dominant prey species consumed by minke whales in sub-area 7W (A) and the catch data of Japanese pilchard, Chub mackerel and Pacific saury in the Pacific side of Japan (B). 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.

Since 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 the prey of minke whales probably reflect changes in the abundance of available prey species in this area. 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 fork length of prey species consumed by minke whales in this study indicates that the minke whales fed primarily on adult of these species, Japanese anchovy (Kondo, 1969), Pacific saury (Odate, 1977) and walleye pollock (Maeda, 1972). These fishes support important commercial fisheries.

Competition between 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 of the total Norwegian catch of herring (Folkow *et al.*, 1997).

Fig. 5 shows the fishing grounds of Pacific saury and the positions of minke whales sightings in sub-area 7W in the survey conducted during 24 August and 5 September 1996 (Fujise *et al.*, 1997). In this season the fishing grounds make two spots off south of Erimo, off Kushiro and Nemuro in days 22 – 25 August. After that, the spot off Erimo Point disappeared and the ground off Kushiro and Nemuro were combined and expanded until September. Most of the minke whales sightings occurred close to these fishing grounds. This observation suggests the relationship between minke whales and Pacific saury from summer to autumn in the western North Pacific.

Tamura and Fujise (2000) estimated seasonal consumption of Pacific saury by minke whales in Pacific side of Japan during August and September, this value was equivalent to 10 – 21 % of the catch of Pacific saury in Japan.

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, comparative research on the distribution and abundance of important prey species such as Pacific saury, and minke whales might be necessary in the future. In addition, more data are urgently needed on seasonal, local and annual variations in the prey of minke whales and minke whales before conclusions can be drawn with regard to their role in the marine ecosystems in the western North Pacific and the southern Okhotsk Sea.

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Table 1. Sub-areas, months and years of surveys and sample size used in this study.

Sub-area	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

Table 2. Prey species found in stomach 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*

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

Number of prey species	Prey species	7W N	7W %	7E N	7E %	8 N	8 %	9 N	9 %	11 N	11 %	Total N	Total %
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	14.5			32	41.6	70	42.7			113	26.5
	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 Observed		76	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 (sub-areas 7, 8 and 9).

A. May

Prey species	% occurrence				% weight ingested				CRI index			
Area	7W	7E	8	9	7W	7E	8	9	7W	7E	8	9
Year		1998	1998	1997		1998	1998	1997		1998	1998	1997
Copepoda												
Euphausiacea				4.3				4.8				4
Cephalopoda												
Japanese flying squid												
Pisces												
Japanese anchovy		97.7	100.0	95.7		97.0	96.8	91.2		1	1	1
Japanese pilchard												
Pacific saury				4.3				4.0				6
Walleye polloek												
Chub mackerel												
Japanese pomfret												
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

B. June

Prey species	% occurrence					% weight ingested					CRI index				
Area	7W	7E	8	9		7W	7E	8	9		7W	7E	8	9	
Year	1999	1997	1998	1995	1997	1999	1997	1998	1995	1997	1999	1997	1998	1995	1997
Copepoda															
Euphausiacea		100.0	3.7	14.3				3.7	8.7			1	4	12	
Cephalopoda															
Japanese flying squid															
Pisces															
Japanese anchovy	90.0	50.0	96.3	42.9	90.9	89.6	55.5	91.8	42.9	90.9	1	4	1	1	1
Japanese pilchard															
Pacific saury			3.7	35.7	9.1			2.9	35.7	9.1			6	4	4
Walleye pollock	12.0					10.4					4				
Chub mackerel							44.5								
Japanese pomfret															
Salmonidae			3.7	14.3				1.6	12.7				8	9	
Other fishes															
No. whales observed	50	2	27	14	33	50	2	27	14	33	50	2	27	14	33

C. July

Prey species	% occurrence						% weight ingested						CRI index					
Area	7W	7E	8		9		7W	7E	8		9		7W	7E	8		9	
Year		1996	1996	1997	1994	1995		1996	1996	1997	1994	1995		1996	1996	1997	1994	1995
Copepoda																		
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
Walleye pollock																		
Chub mackerel																		
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

Table 4. Continued.

D. August

Prey species	% occurrence					% weight ingested					CRI index				
Area	7W	7E	8	9		7W	7E	8	9		7W	7E	8	9	
Year	1996		1996	1994	1995	1996		1996	1994	1995	1996		1996	1994	1995
Copepoda					5.0					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
Salmonidae															
Other fishes					5.0					5.0					9
No. whales observed	13		5	9	20	13		5	9	20	13		5	9	20

E. September

Prey species	% occurrence				% weight ingested				CRI index			
Area	7W	7E	8	9	7W	7E	8	9	7W	7E	8	9
Year	1996			1994	1996			1994	1996			1994
Copepoda												
Euphausiacea	53.8			50.0	48.0			50.0	1			1
Cephalopoda												
Japanese flying squid												
Pisces												
Japanese anchovy												
Japanese pilchard												
Pacific saury	38.5			25.0	32.9			25.0	4			4
Walleye pollock	23.1				19.1				9			
Chub mackerel												
Japanese pomfret				25.0				25.0				4
Salmonidae												
Other fishes												
No. whales observed	13			4	13			4	13			4

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

A. July (1999)

Prey species	% occurrence	% weight ingested	CRI index
Copepoda			
Euphausiacea	87.5	90.0	1
Cephalopoda			
Japanese flying squid			
Pisces			
Japanese anchovy	12.5	10.0	4
Japanese pilchard			
Pacific saury			
Walleye pollock			
Chub mackerel			
Japanese pomfret			
Salmonidae			
Other fishes			
No. whales observed	40	40	40

B. August (1996)

Prey species	% occurrence	% weight ingested	CRI index
Copepoda			
Euphausiacea	100.0	100.0	1
Cephalopoda			
Japanese flying squid			
Pisces			
Japanese anchovy			
Japanese pilchard			
Pacific saury			
Walleye pollock			
Chub mackerel			
Japanese pomfret			
Salmonidae			
Other fishes			
No. whales observed	22	22	22

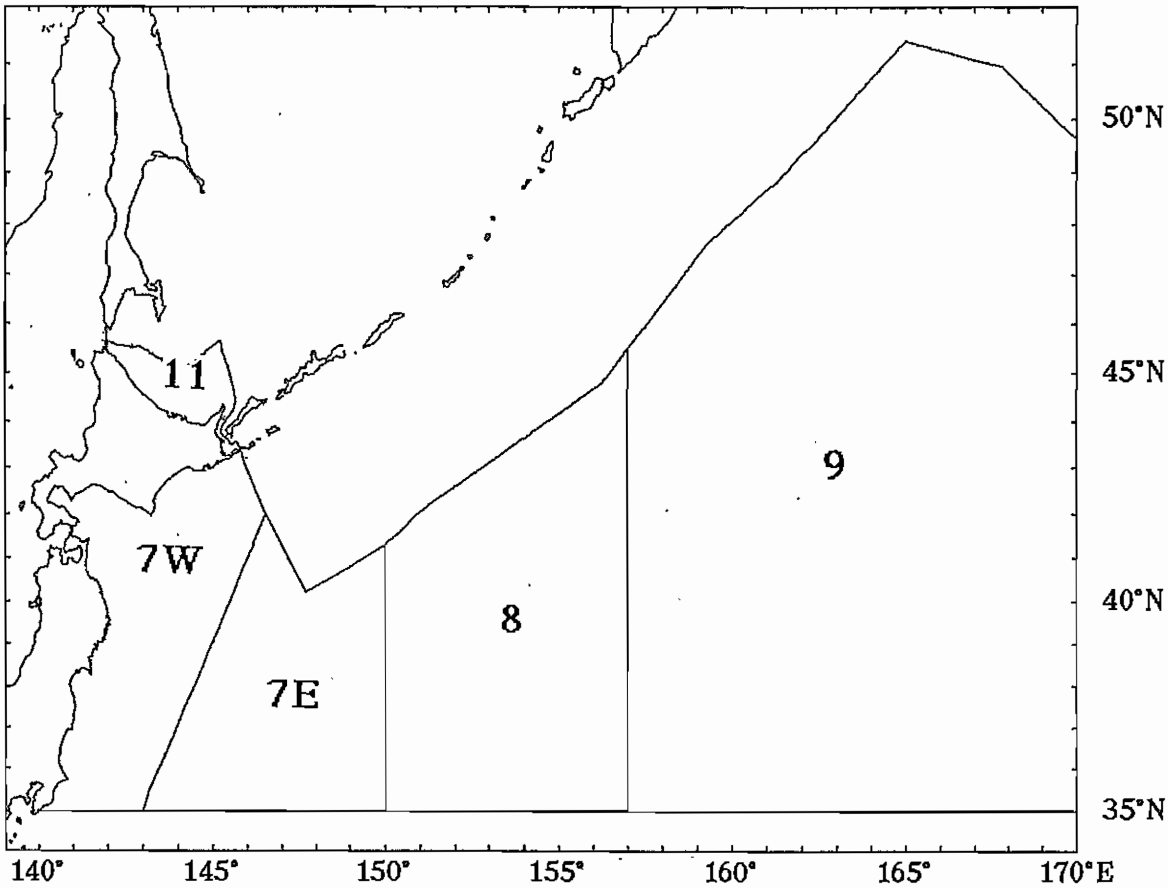


Fig.1. Sub-areas surveyed by the JARPN from 1994 to 1999. Sub-areas were based on IWC (1994), excluding the EEZ of Russia. Furthermore, sub-area 7 was divided into east (7E) and west (7W).

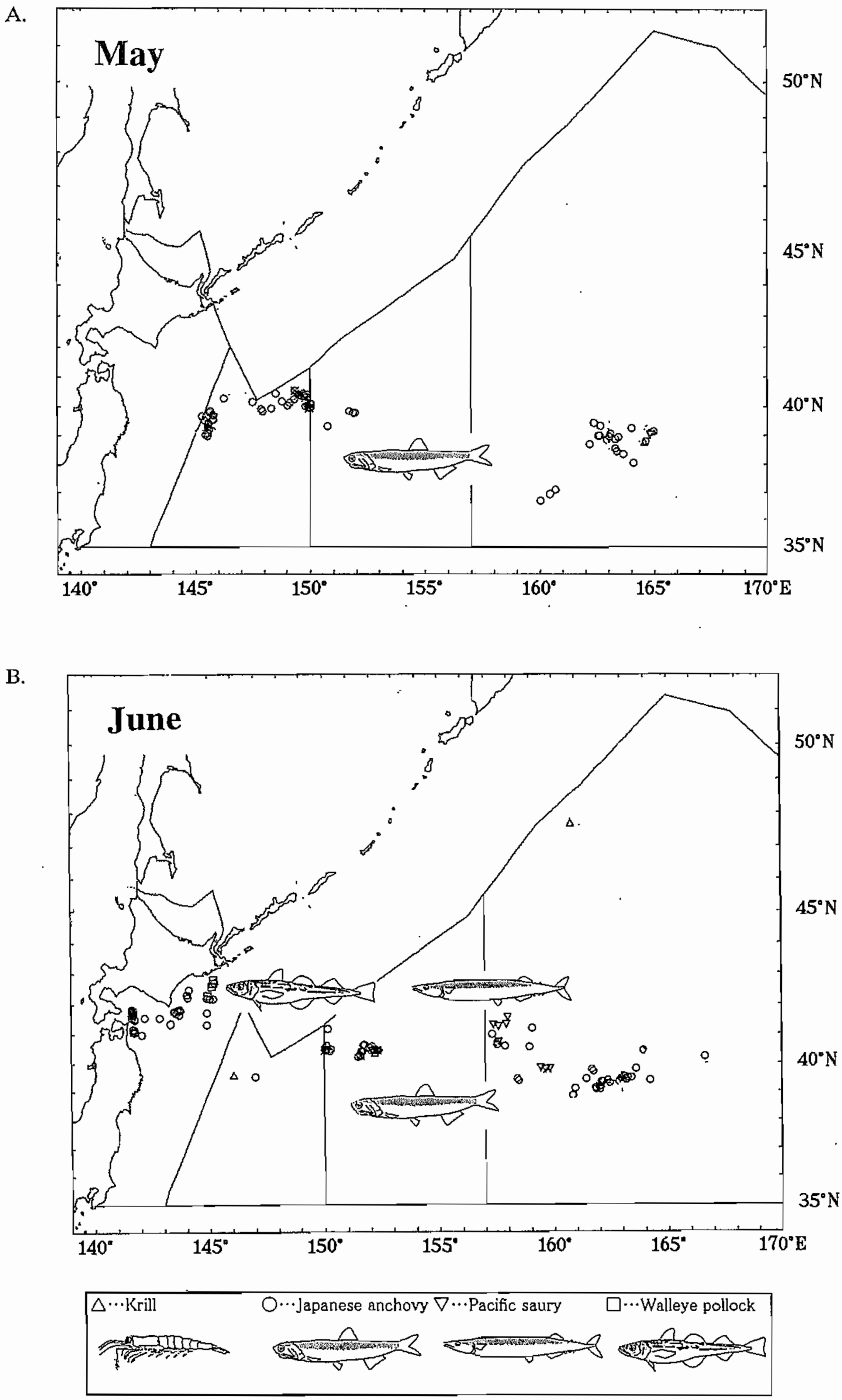


Fig.2. Temporal distribution of minke whales sampled and its dominant prey species.

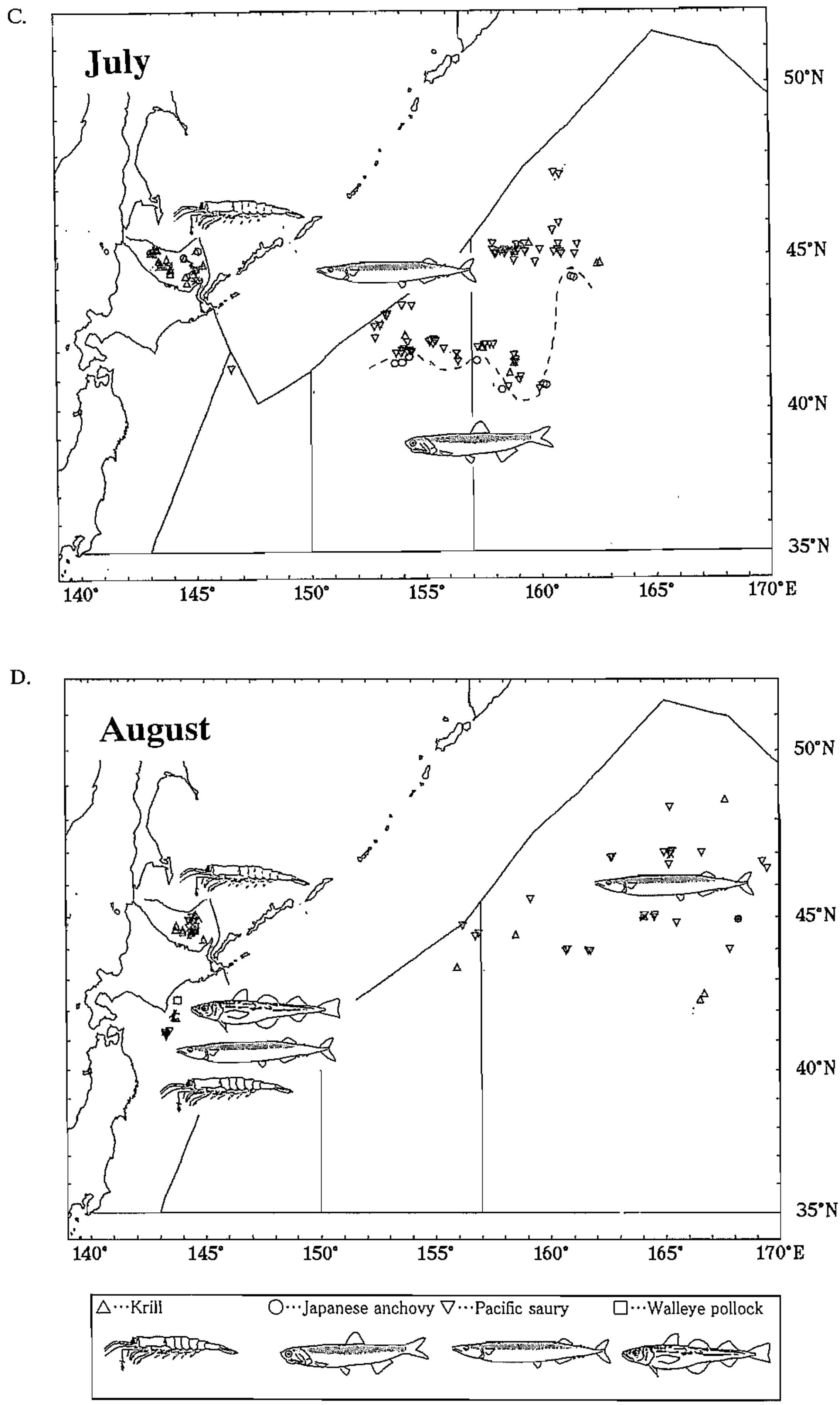


Fig.2. Continued.

E.

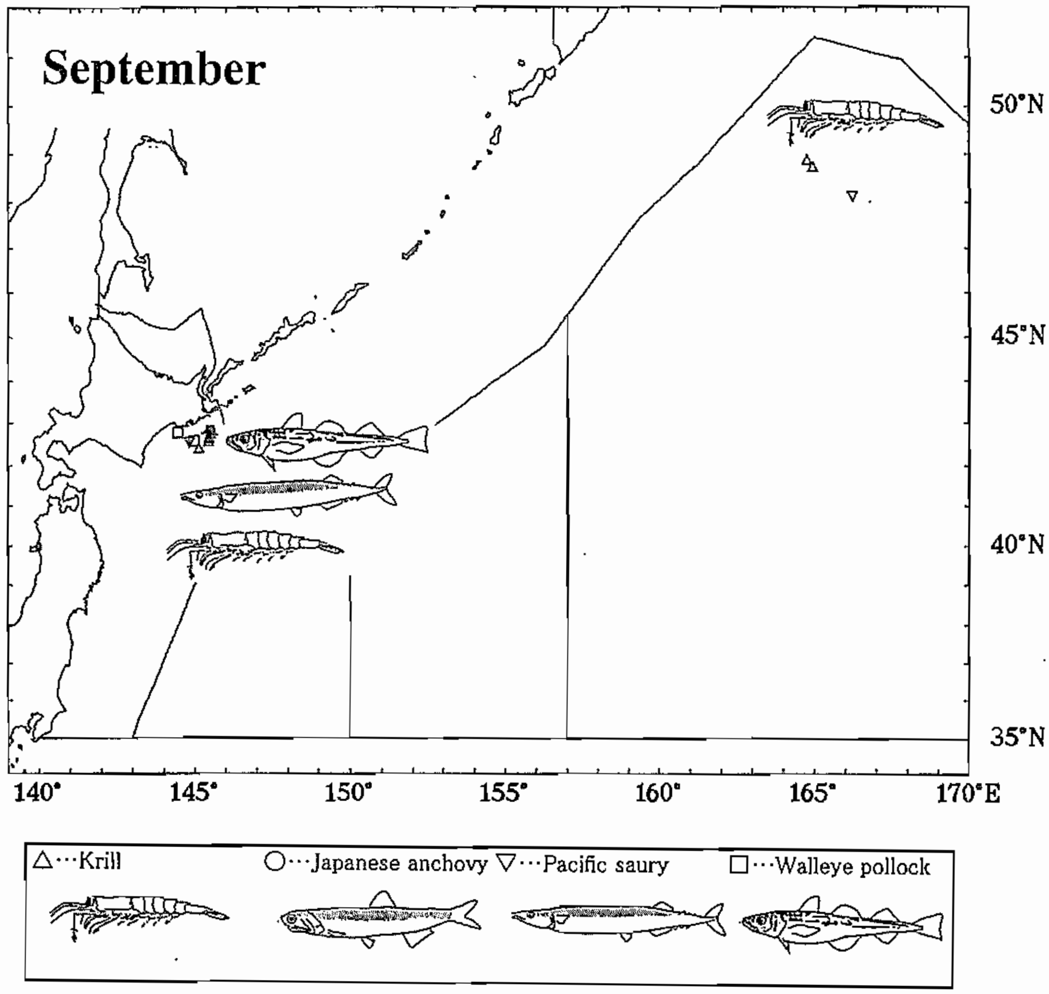


Fig.2. Continued.

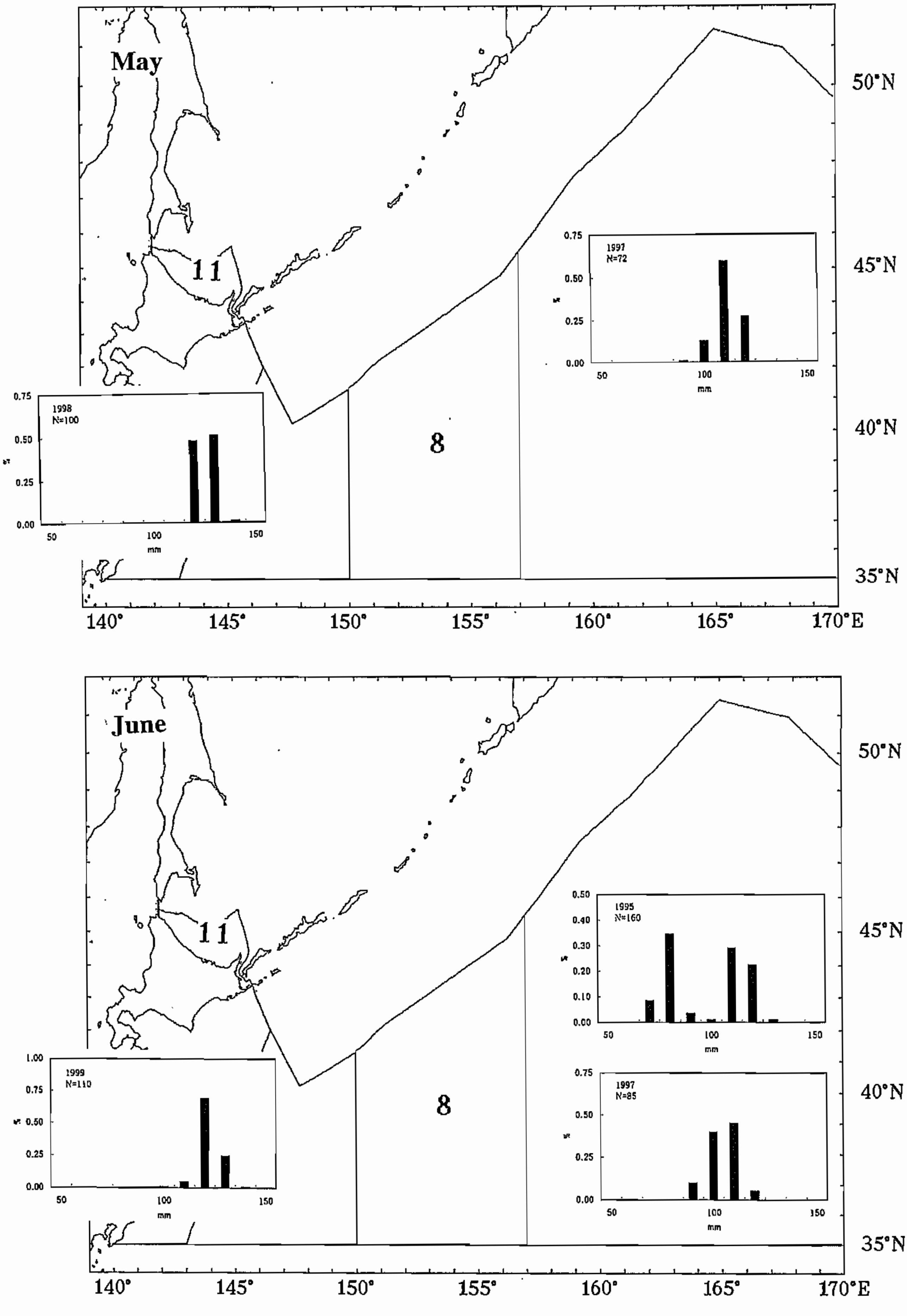
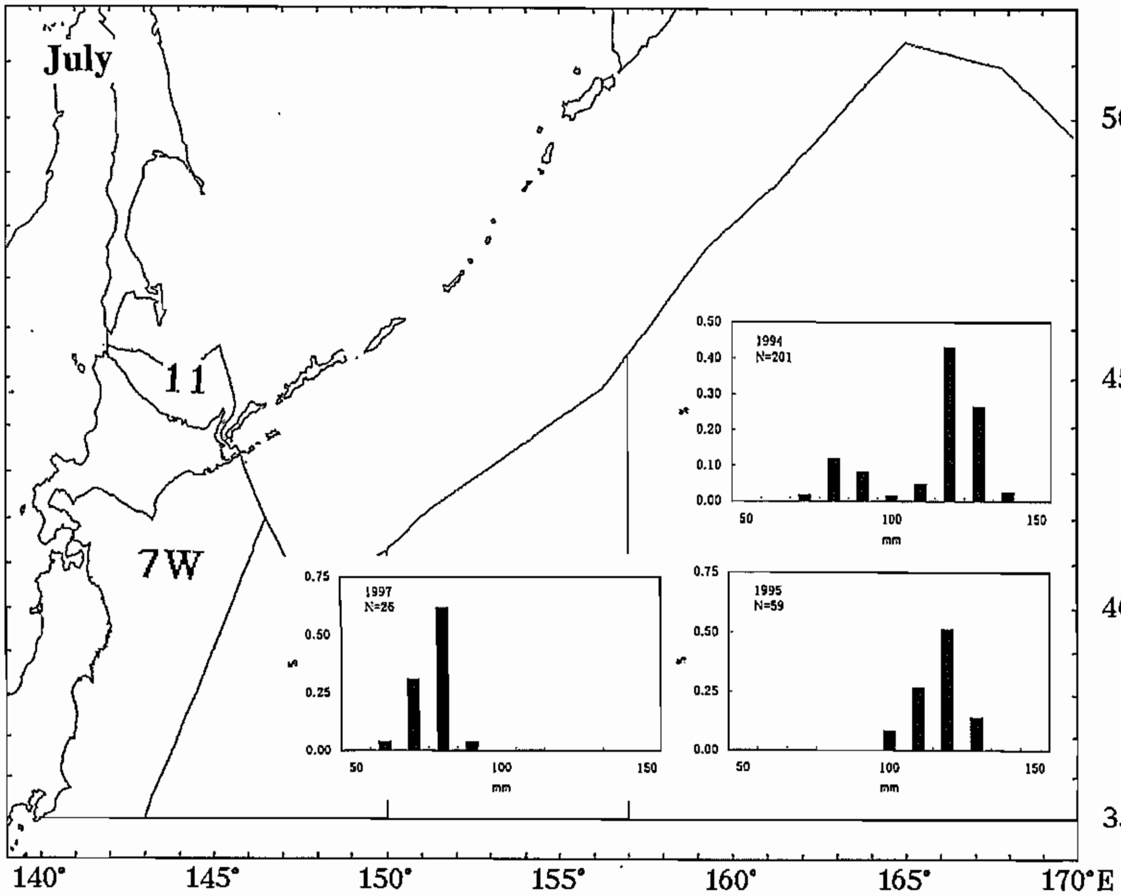


Fig.3A. Fork length frequency of Japanese anchovy consumed by minke whales in the western North Pacific.



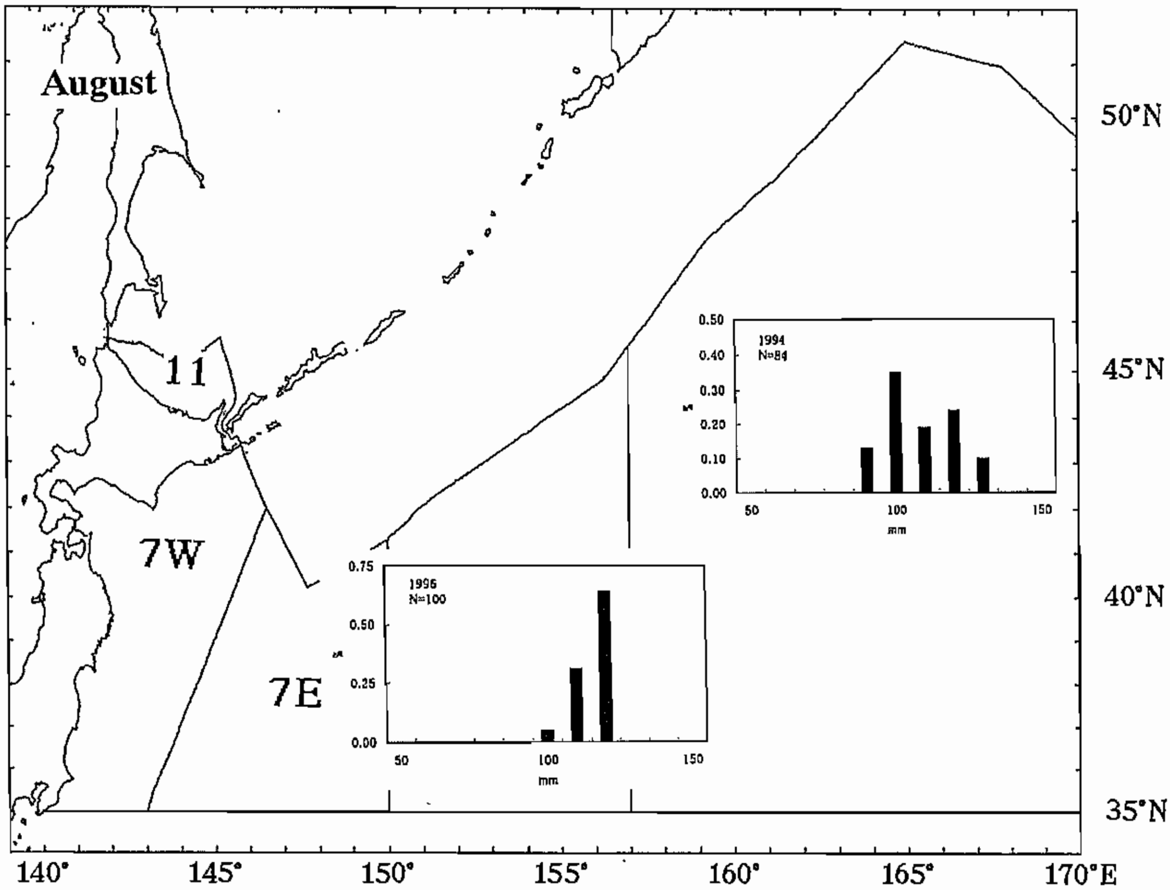


Fig.3A. Continued.

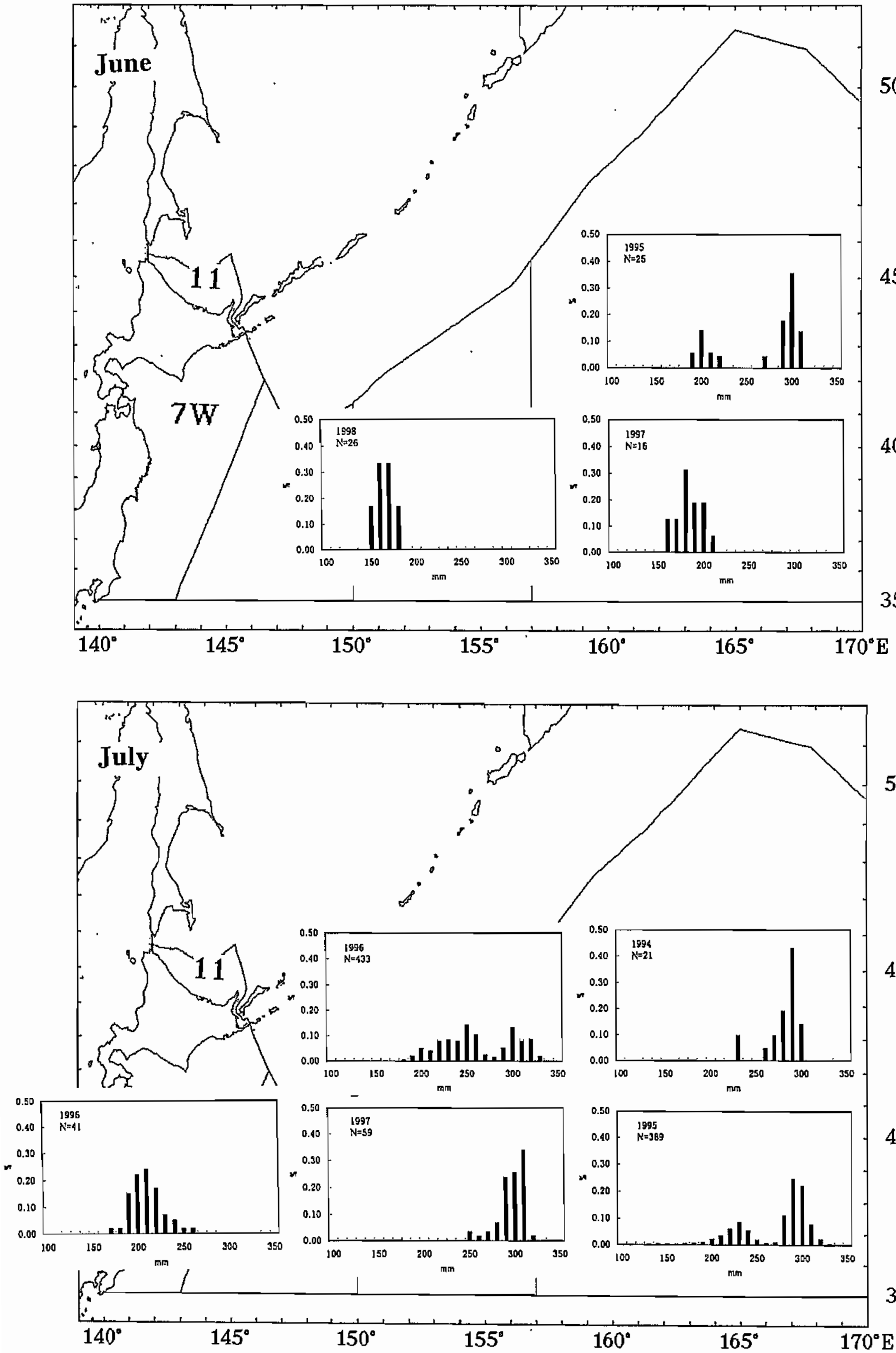
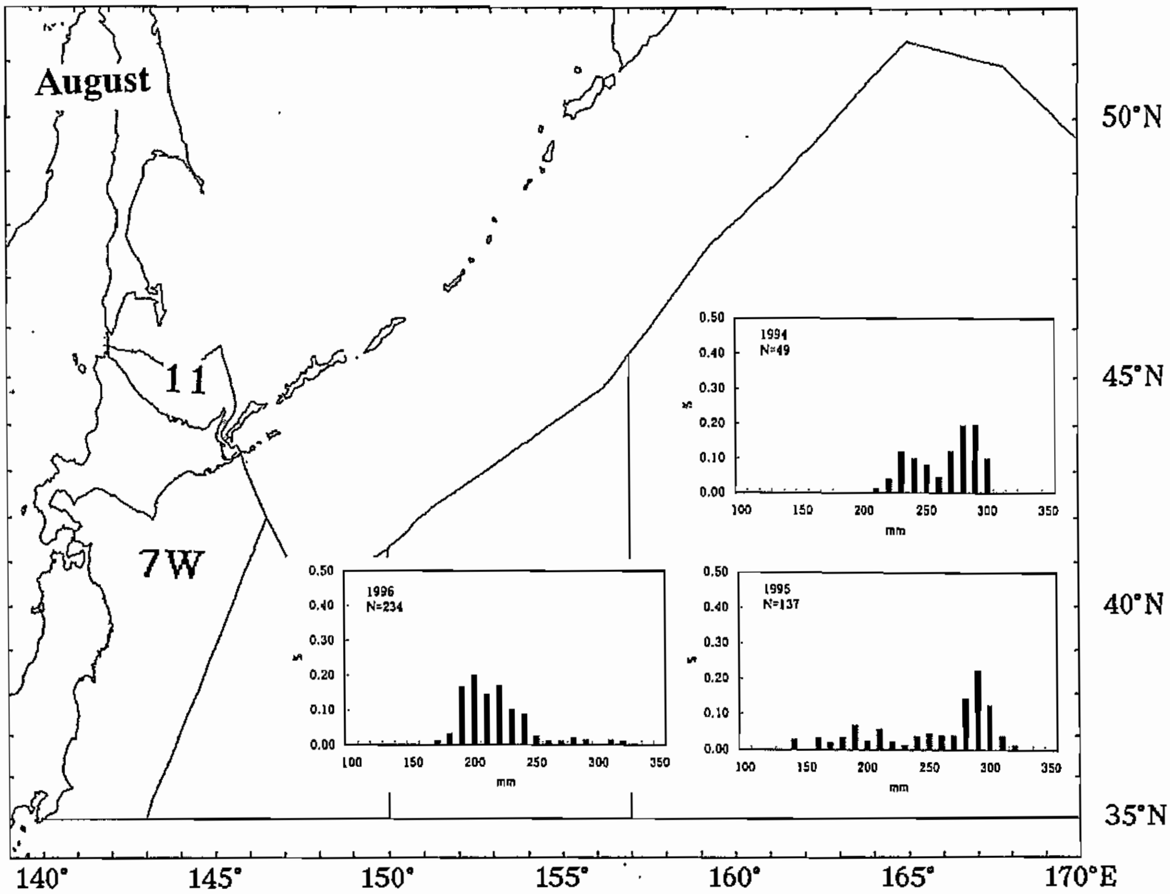


Fig.3B. Fork length frequency of Pacific saury consumed by minke whales in the western North Pacific.



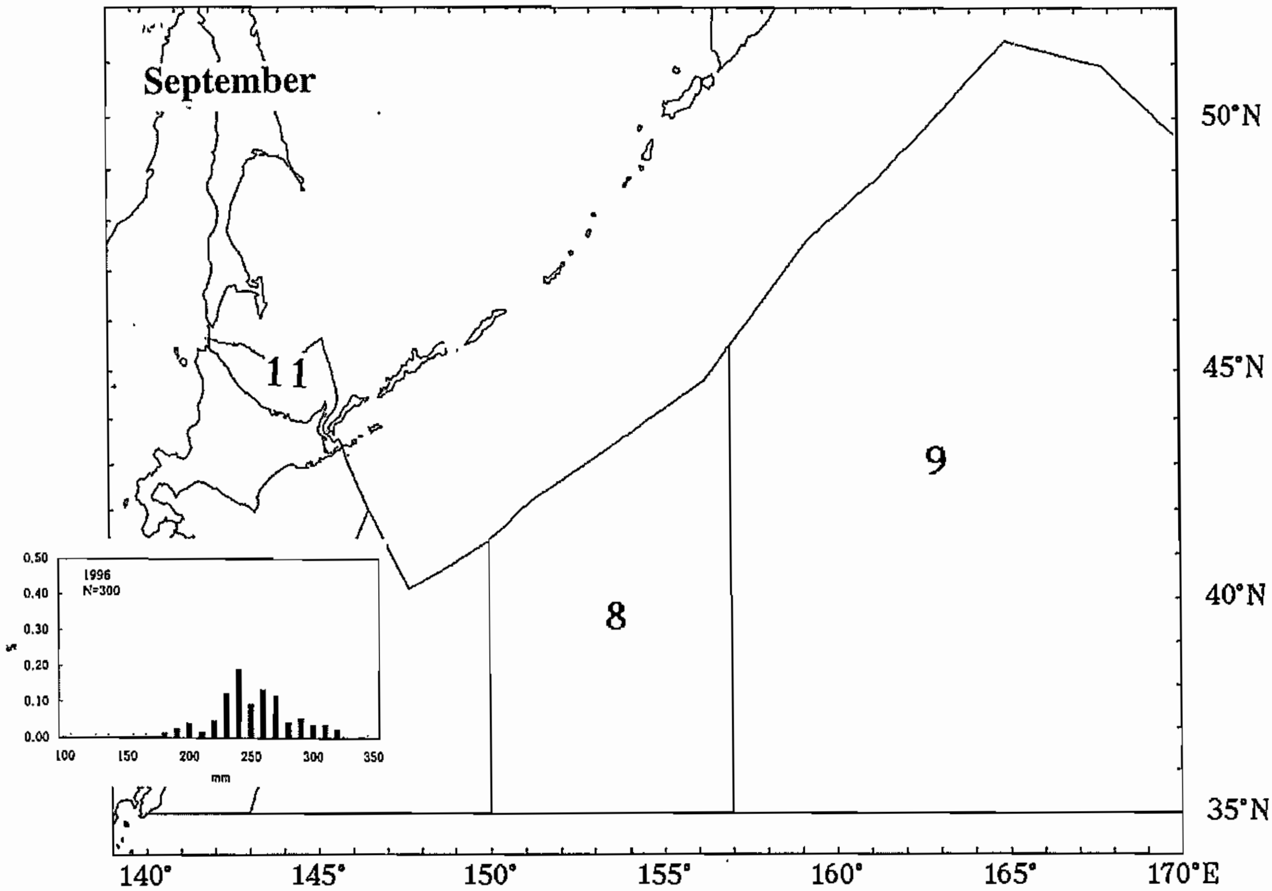


Fig.3B. Continued.

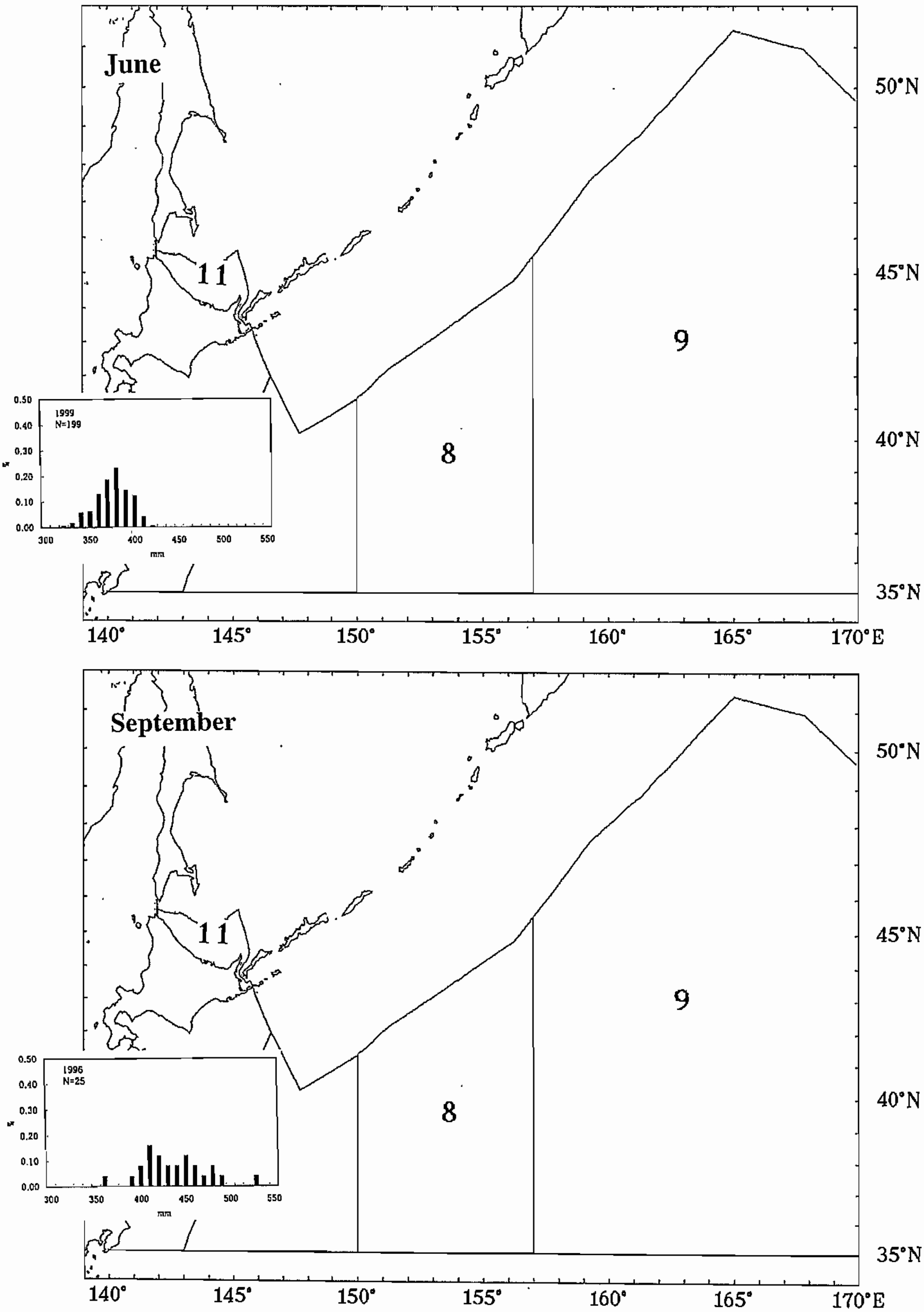


Fig.3C. Fork length frequency of walleye pollock consumed by minke whales in the western North Pacific.

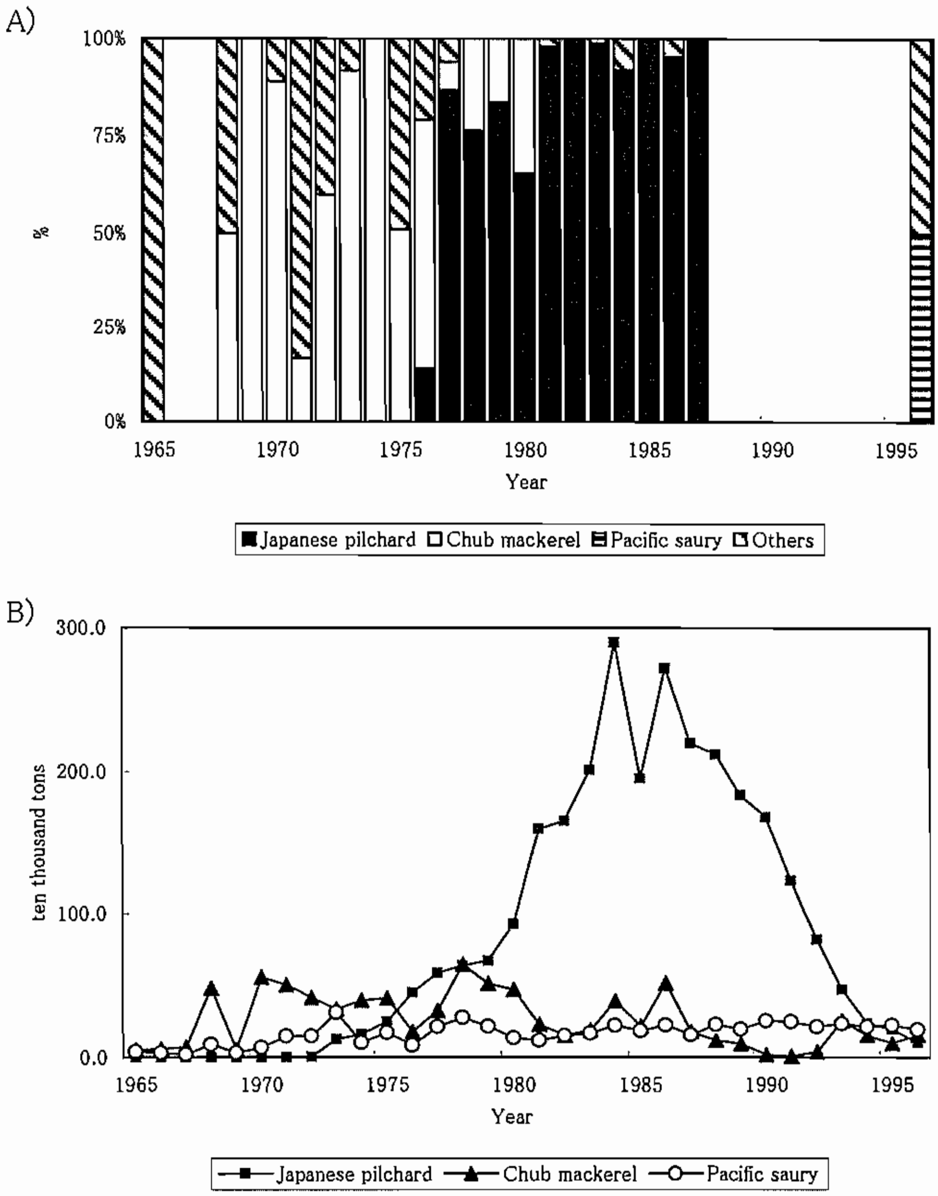


Fig.4. The annual change of relative frequency of occurrence of each dominant prey specie consumed by minke whale in sub-area 7W (A) and commercial catch in Pacific side (The ministry of Agriculture, Forestry and Fisheries of Japan, 1967-1999; Kasamatsu and Tanaka, 1992; this study)

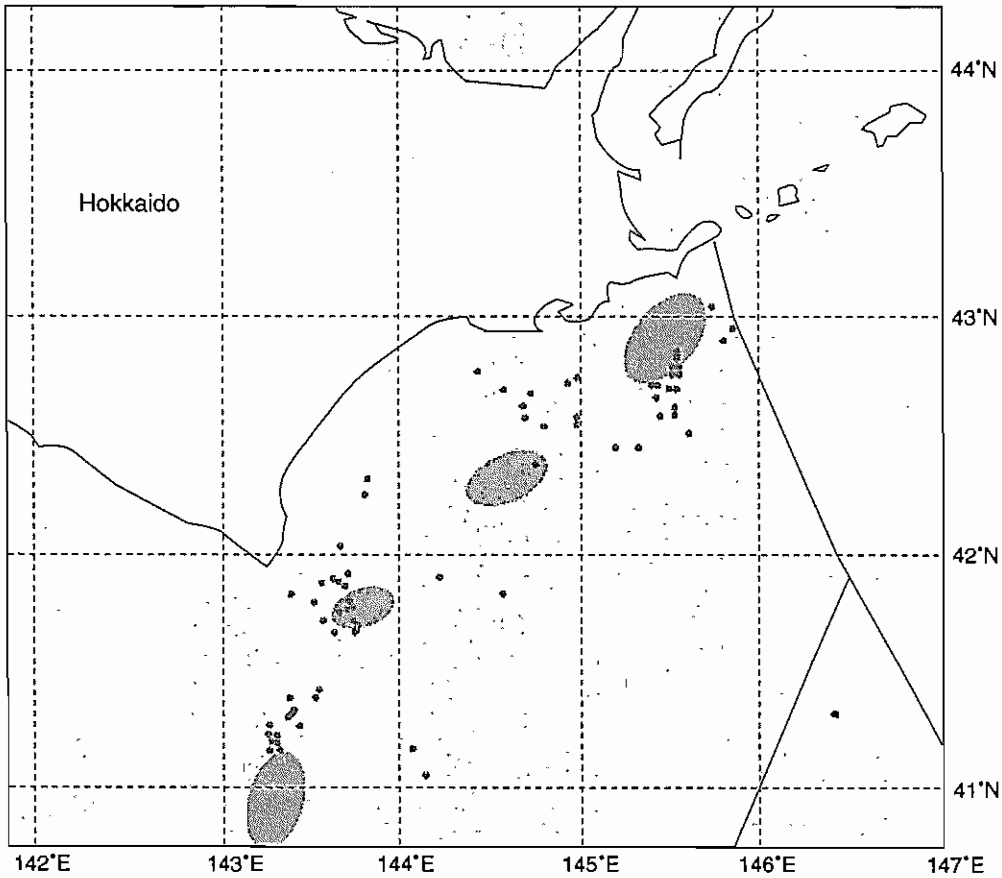


Fig.5. Relationship between minke whale sightings and the fishing ground of Pacific saury in the sub-area 7W during 22 July and 8 September 1996. The information of the fishing grounds was obtained from the telex Nos. 27 - 33 on fishing grounds off the Pacific coast of eastern Hokkaido by the Fishing Information Service Center in Japan (Redrawn from Fujise *et al.* 1997).