Daily and seasonal food consumption by the western North Pacific minke whale

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ABSTRACT

Daily food consumption of the western North Pacific minke whale was estimated using two methods: 1) diurnal change in the forestomach and fundus content weight and 2) field metabolism. We examined 498 forestomach and fundus of minke whales sampled by JARPN surveys from 1994 to 1999. Estimations were made by sexual maturity stage. Estimates of the daily food consumption rate obtained by the method–1 were 3.9 – 5.7 and 2.6 – 3.9 % of body weight if the proportion of the rest of food after 8 hours was 5 and 20 %, respectively. Estimates of the daily food consumption rate obtained by the method–2, ranged from 1.8 to 5.2 % of body weight. These values were similar to the estimates of eastern North Atlantic minke whales and the Antarctic minke whale. The estimated total consumption of prey species by minke whales in Pacific side of Japan during August and September were $2.1 - 4.0 \times 10^4$ tons for krill, $0.4 - 0.6 \times 10^4$ tons for Japanese anchovy, $2.8 - 6.2 \times 10^4$ tons for Pacific saury and $0.3 - 0.4 \times 10^4$ tons for walleye pollock, respectively. Total consumption of krill by minke whales in southern Okhotsk Sea during August and September were $1.4 - 2.2 \times 10^4$ tons by two methods.

INTRODUCTION

The minke whale *Balaenoptera acutorostrata* is widely distributed in the world oceans. 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 is estimated to be 19,209 animals with 95 % confidence interval (10,069 – 36,645) in the Okhotsk Sea (sub areas 11 and 12) and 5,841 animals with 95 % confidence interval (2,835 – 12,032) in the Northwest Pacific (sub areas 7, 8 and 9) during August and September in 1989 and 1990 (IWC, 1992).

Some researchers estimated the food consumption by minke whales on the basis of energy-requirements calculations (Hinga, 1979; Lockyer, 1981a; Armstrong and Siegfried, 1991; Tamura *et* *al.*, 1997). However these estimates were based on parameters extrapolated from the Antarctic and eastern North Atlantic minke whale. Tamura and Fujise (2000A) reported that krill (*Euphausia pacifica*, *Thysanoessa longipes*, *T. inermis*, *T. inspinata*), Japanese anchovy *Engraulis japonicus*, Pacific saury *Cololabis saira*, walleye pollock *Theragra chalcogramma* were the dominant prey species in the Pacific side (sub-areas 7W, 7E, 8 and 9) and that krill (*E. pacifica*, *T. longipes*) was the dominant prey species in the southern Okhotsk Sea (sub-area 11).

In this paper we targeted the Japanese anchovy, Pacific saury, walleye pollock and krill in the Pacific side of Japan and krill in the southern Okhotsk Sea, and we estimated the amount of food consumed by the western North Pacific minke whale using two different methods. In these two methods we used several biological parameters obtained directly from the western North Pacific minke whale through JARPN surveys.

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). However, mixing of contents have occurred through the relatively large hole between the forestomach and the fundic chumber (Olsen *et al.*, 1994). The prey species composition of forestomach and fundus were very similar (Lindstrøm *et al.*, 1997; Tamura and Fujise, 2000A). Therefore, the analyses of this study were based on contents from forestomach and fundus contents.

The forestomach and fundus contents were removed on the ship's flensing deck within eight hours after capture. Then, forestomach and fundus contents were weighed to the nearest 0.1 kg. We estimated the total weight of each prey (Japanese anchovy, Pacific saury, walleye pollock, total in the Pacific side of Japan and krill in the southern Okhotsk Sea) by using the results from the sub-sample.

Estimation of daily food consumption

Estimation of daily food consumption from diurnal change in stomach content weight (Method-1)

Miura (1969) proposed a method for estimating daily food consumption from diurnal changes in stomach content weight (Vi) with the time of passage based on a known digestion rate in the stomach. If the proportion of food digested during an interval is d and the proportion of rest of food (S) is 1-d, the amount of food consumed (Ci) is given by the following equations:

$$t_1: C_1 = V_1$$
$$t_2: C_2 = V_2 - SV_1$$
$$t_3: C_3 = V_3 - SV_2 - S^2V_1$$
$$t_i: C_i = V_i - SV_{i-1} - S^2V_{i-2} \cdots - S^{i-1}V_1$$

Therefore the daily food consumption ($\sum_{i=1}^{k} C_i$) is given by:

$$\sum_{i=1}^{k} Ci = V_1 \frac{(1-2S+S^k)}{1-S} + V_2 \frac{(1-2S+S^{k-1})}{1-S} + \cdots + V_{k-1}(1-S) + \cdots + V_k$$

In this analysis we expressed the mean forestomach and fundus content weight as percentage of body weight (Vi) at 1 hour intervals for each dominant prey species (Pacific side of Japan: Japanese anchovy, Pacific saury and total; southern Okhotsk Sea: krill). Assuming that food takes 8 hours to digested the stomach contents (Tobayama, 1974; Bushuev, 1986; Sekiguchi, 1994) and that d is exponential (Elliott and Persson, 1978), we estimated S to be 0.69 and 0.82 if the proportion of the rest of food after 8 hours is 5 % and 20 %, respectively.

In this method we assumed that minke whales did not feed during night (Folkow and Blix, 1993; Zhongxue *et al.*, 1983, Haug *et al.*, 1997, Tamura and Fujise, 2000B). Estimations were made by sex and sexual maturity stage.

Estimation of daily food consumption from the field metabolism (Method-2)

We calculated the daily consumption of each prey species (F) by different maturity stages of minke whale from the field metabolic rate (FMR) according to the following equations:

Immature male or female: $F\ (\text{kg day}^{-1}) = \{FMR \times 365 / (D+185 \times 0.1) / E+G\} / A$

Mature male: $F\ (\text{kg day}^{-1}) = FMR \times 365 / (D+185 \times 0.1) / E / A$

Mature female: $F\ (\text{kg day}^{-1}) = \{FMR \times 365 / (D+185 \times 0.1) / E+R\} / A$

FMR : Field metabolic rate (kJ day^{-1})
D : Residence time (days)
E : Caloric value of prey species (kJ kg^{-1})

G	: Growth cost (kg day^{-1})
R	: Reproduction cost (kJ day^{-1})
A	: Assimilation efficiency

The following assumptions were made for both methods.

A: Mean body weight (W)

We calculated mean body weight of 2,400 kg and 2,500 kg for immature male and female, respectively. For mature male and female were 4,500 kg and 5,500 kg, respectively. These weights were obtained during JARPN survey data.

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

We assumed that minke whales spend about 180 days in the feeding areas in the western North Pacific (Ohsumi, 1980, 1982). Lockyer (1981b) reported that the daily food consumption of minke whale in winter was equivalent to 10 % of that in the summer. We adopted these assumptions for estimating the feeding days.

The following assumptions were made for method-2.

C: Field metabolic rate (FMR)

We calculated the FMR according to Blix and Folkow (1995):

$$FMR = 80W \text{ (kJ day}^{-1}\text{)}$$

The average FMR used in these calculations was obtained from Blix and Folkow (1995). The value used of 80 kJ/kg per day is based on indirect determination of oxygen consumption from studies of the respiratory rates of a number of similar sized free swimming minke whales performing different activities, such as feeding, cruising and sleeping. Additional data on lung volumes, oxygen extraction and tidal volume were also used in these calculations.

D: Caloric value of prey species (E)

Stomach contents analyses show much variation in the diet of minke 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 krill, Japanese anchovy and Pacific saury were assumed to be 3,900 kJ kg^{-1}, 5,500 kJ kg^{-1} and 10,000 kJ kg^{-1}, respectively (Resource Council, Science and Technology Agency Japan, 1995).

The mean caloric value of walleye pollock was assumed to be 4,600 kJ kg^{-1} (Perez, 1994). Total prey species were assumed to be 6,000 kJ kg^{-1} by average of above values.

E: Growth cost (*G*)

The cost of growth was assumed to be 3.0 kg per day (Lockyer, 1981b).

F: Reproduction cost (*R*)

The total reproductive cost for a female minke whales was re-calculated to be 1.9×10^7 kJ, assuming a length at birth fetus of 273 kg (Christensen, 1981). The pregnancy rate is 89 % for mature females in the western North Pacific (from the JARPN survey data). We assumed that all energy related to reproduction costs as obtained during the residence (feeding) time in the western North Pacific (*D*).

G: Assimilation efficiency (*A*)

We assumed that minke whales have an assimilation efficiency of 80 % (Markussen *et al.*, 1992).

Estimation of total food consumption in each sub-area during August and September

We extrapolated the food consumption by minke whale during August and September in each sub-area by multiplying the abundance estimates by the wet weight composition of prey consumed. The following assumptions were made for both methods.

A: Abundance estimates

The abundance estimates used to condition the implementation simulation trials were used. These estimates were calculated from results of sighting surveys during August and September (IWC, 1997). We divided abundance estimates according the sexual maturity rates obtained from JARPN surveys in each sub-area (Table 3).

B: Wet weight composition (%) of prey consumed

We calculated the wet weight composition of each prey species in each sub-area in August and September by using data of JARPN surveys (Table 4).

RESULTS

Estimation of daily food consumption by Method-1

Japanese anchovy (Pacific side of Japan)

Fig. 2 shows the diurnal change with time (hourly) of the mean forestomach and fundus content weight as percentage of body weight. There is no substantial change in a day. The daily food consumption rates were calculated to be 5.7 and 3.9 % of body weight for both sexes if the proportion of undigested food after 8 hours was 5 and 20 %, respectively. The estimated food consumption weights were 94.3 – 135.8 kg and 98.3 – 141.5 kg for immature male and female, respectively and 176.9 – 254.7 kg and 216.2 – 311.3 kg for mature male and female, respectively (Table 2A).

Pacific saury (Pacific side of Japan)

Fig. 3 shows the diurnal change with time (hourly) of the mean forestomach and fundus content weight as percentage of body weight. There is no substantial change in a day. The daily food consumption rates were calculated to be 4.2 and 3.0 % of body weight for both sexes if the proportion of undigested food after 8 hours was 5 and 20 %, respectively. The estimated food consumption weights were 72.0 – 100.8 kg and 75.0 – 105.0 kg for immature male and female, respectively and 135.0 – 189.0 kg and 165.0 – 231.0 kg for mature male and female, respectively (Table 2B).

Total prey species (Pacific side of Japan)

Fig. 4 shows the diurnal change with time (hourly) of the mean forestomach and fundus content weight as percentage of body weight. There is no substantial change in a day. The daily food consumption rates were calculated to be 5.3 and 3.7 % of body weight for both sexes if the proportion of undigested food after 8 hours was 5 and 20 %, respectively. The estimated food consumption weights were 94.3 – 135.8 kg and 98.3 – 141.5 kg for immature male and female, respectively and 176.9 – 254.7 kg and 216.2 – 311.3 kg for mature male and female, respectively (Table 2C).

Krill (southern Okhotsk Sea)

Fig. 5 shows the diurnal change with time (hourly) of the mean forestomach and fundus content weight as percentage of body weight. There is no substantial change in a day, though data are not sufficient. The daily food consumption rates were calculated to be 3.9 and 2.6 % of body weight for both sexes if the proportion of undigested food after 8 hours was 5 and 20 %. The estimated food consumption weights were 63.4 – 92.9 kg and 66.0 – 96.8kg for immature male and female, respectively and 118.8 – 174.2 kg and 145.2 – 212.9 kg for mature male and female, respectively (Table 2E).

Estimation of daily food consumption by Method-2

Japanese anchovy (Pacific side of Japan)

The estimated food consumption weights were 84.0 kg (3.5 % of body weight) and 87.3 kg (3.5 % of body weight) for immature male and female, respectively and 150.5 kg (3.3 % of body weight) and

203.2 kg (3.7 % of body weight) for mature male and female, respectively (Table 2A).

Pacific saury (Pacific side of Japan)

The estimated food consumption weights were 47.9 kg (2.0 % of body weight) and 49.7 kg (2.0 % of body weight) for immature male and female, respectively and 82.8 kg (1.8 % of body weight) and 111.8 kg (2.0 % of body weight) for mature male and female, respectively (Table 2B).

Walleye pollock (Pacific side of Japan)

The estimated food consumption weights were 99.7 kg (4.2 % of body weight) and 103.7 kg (4.2 % of body weight) for immature male and female, respectively and 179.9 kg (4.0 % of body weight) and 243.0 kg (4.4 % of body weight) for mature male and female, respectively (Table 2C).

Total prey species (Pacific side of Japan)

The estimated food consumption weights for all prey species were 77.3 kg (3.2 % of body weight) and 80.4 kg (3.2 % of body weight) for immature male and female, respectively and 137.9 kg (3.1 % of body weight) and 186.3 kg (3.4 % of body weight) for mature male and female, respectively (Table 2D).

Krill (southern Okhotsk Sea)

The estimated food consumption weights were 116.9 kg (4.9 % of body weight) and 121.6 kg (4.9 % of body weight) for immature male and female, respectively and 212.2 kg (4.7 % of body weight) and 286.6 kg (5.2 % of body weight) for mature male and female, respectively (Table 2E).

Estimation of food consumption in each sub-area by Method-1

Total consumption of krill, Japanese anchovy, Pacific saury and walleye pollock in Pacific side of Japan during August and September were 2.1 – 3.2×10^4 tons, 0.5 – 0.8×10^4 tons, 4.5 – 6.2×10^4 tons and 0.3 – 0.4×10^4 tons, respectively. Total consumption of krill in southern Okhotsk Sea during August and September were 1.4 – 2.2×10^4 tons (Table 7).

Estimation of food consumption in each sub area by Method-2

Total consumption of krill, Japanese anchovy, Pacific saury and walleye pollock in Pacific side of Japan during August and September were 4.0×10^4 tons, 0.4×10^4 tons, 2.8×10^4 tons and 0.3×10^4 tons, respectively. Total consumption of krill in southern Okhotsk Sea during August and September were 1.4×10^4 tons (Table 8).

DISCUSSION

Estimation of daily food consumption

The estimates of the daily food consumption rate obtained by the two methods, were not substantially different. However, there are same aspects of these methods, which should be considered. Firstly under method-1, we considered that minke whales do not feed during night (Folkow and Blix, 1993; Zhongxue *et al.,* 1983, Tamura and Fujise, 2000B). If feeding activity also occurred at night, the daily food consumption rates using method-1 would underestimate the actual food consumption rates. Furthermore, we made assumptions on the digestion rate in the stomach, which was the same for all prey species. These rates might be different by prey species. It might be necessary to collect more information on the digestion rate of each prey species in the future.

Regarding to method-2, data was lacked on the information of caloric value of prey species for each sub-area and month. The caloric value of prey species might change among areas and months. For example the caloric value of Pacific saury was known to change during northward migration (spring) and during southward-migration (autumn) (Odate, 1977). It might be necessary to obtain more information on the caloric value of prey species on seasonal, areal and annual basis in the future.

Any estimate of the daily food consumption rate obtained by the two methods in our study was similar to the estimates by Markussen *et al.* (1992), which investigated the eastern North Atlantic minke whales and these obtained by Tamura *et al.* (1997), which investigated the Antarctic minke whales.

In the future, we might estimate to daily food consumption from the energetic costs of blubber deposition and visceral fat deposition in the western North Pacific minke whales. Folkow *et al.* (2000) estimated the food consumption in the Northeast Atlantic minke whales by calculated the deposited energy.

Estimation of food consumption in feeding area

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 eastern North Atlantic. This is more than half of the total Norwegian catch of herring (Folkow *et al.*, 2000). Fujise *et al.* (1997) reported that most of the minke whales sightings in the Pacific side of Hokkaido occurred close to Pacific saury's fishing grounds.

The catch of Pacific saury were 29×10^4 tons and 15×10^4 tons in Japan and Hokkaido in 1997, This value of consumption of Pacific saury by minke whales in Pacific side of Japan during August and September 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 from spring to autumn is insufficient to examine this relationship. For example, we were made many assumptions to estimate food consumption in feeding area. Minke whales migrate into high latitude in summer for feeding and into low latitude in winter for breeding and they feed several prey species from spring to autumn. The information of residence time and abundance in each area and month was insufficient to estimate food consumption in the feeding area.

Therefore, comparative research on the distribution and abundance of important prey species such as Pacific saury, Japanese anchovy, walleye pollock, krill and minke whales might be necessary in the future. In addition, more data are needed on seasonal, local and annual variations in the prey of minke whales before conclusions can be drawn with regard to their food consumption of minke whales in western North Pacific and southern Okhotsk Sea from spring to autumn.

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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. Estimated daily food consumption (kg and as % of body weight) during feeding period by minke whales based on two different methods*.

A. Japanese anchovy

Sex maturity	Body weight	Method-1(20%)		Method-1(5%)		Method-2	
	kg	kg	%	kg	%	kg	%
Immature male	2,400	94.3	3.9	135.8	5.7	84.0	3.5
Immature female	2,500	98.3	3.9	141.5	5.7	87.3	3.5
Mature male	4,500	176.9	3.9	254.7	5.7	150.5	3.3
Mature female	5,500	216.2	3.9	311.3	5.7	203.2	3.7

B. Pacific saury

Sex maturity	Body weight	Method-1(20%)		Method-1(5%)		Method-2	
	kg	kg	%	kg	%	kg	%
Immature male	2,400	72.0	3.0	100.8	4.2	47.9	2.0
Immature female	2,500	75.0	3.0	105.0	4.2	49.7	2.0
Mature male	4,500	135.0	3.0	189.0	4.2	82.8	1.8
Mature female	5,500	165.0	3.0	231.0	4.2	111.8	2.0

C. Walleye pollock

Sex maturity	Body weight	Method-1(20%)		Method-1(5%)		Method-2	
	kg	kg	%	kg	%	kg	%
Immature male	2,400	N.D.	N.D.	N.D.	N.D.	99.7	4.2
Immature female	2,500	N.D.	N.D.	N.D.	N.D.	103.7	4.2
Mature male	4,500	N.D.	N.D.	N.D.	N.D.	179.9	4.0
Mature female	5,500	N.D.	N.D.	N.D.	N.D.	243.0	4.4

D. Others

Sex maturity	Body weight	Method-1(20%)		Method-1(5%)		Method-2	
	kg	kg	%	kg	%	kg	%
Immature male	2,400	94.3	3.7	135.8	5.3	77.3	3.2
Immature female	2,500	98.3	3.7	141.5	5.3	80.4	3.2
Mature male	4,500	176.9	3.7	254.7	5.3	137.9	3.1
Mature female	5,500	216.2	3.7	311.3	5.3	186.3	3.4

E. Krill

Sex maturity	Body weight	Method-1(20%)		Method-1(5%)		Method-2	
	kg	kg	%	kg	%	kg	%
Immature male	2,400	63.4	2.6	92.9	3.9	116.9	4.9
Immature female	2,500	66.0	2.6	96.8	3.9	121.6	4.9
Mature male	4,500	118.8	2.6	174.2	3.9	212.2	4.7
Mature female	5,500	145.2	2.6	212.9	3.9	286.6	5.2

*: See text

Table 3. Estimates of minke whales in each sub-area.

	Male		Female		
Sub-area	Immature	Mature	Immature	Mature	Total*
7	349	1,583	143	127	2,202
8	93	906	23	35	1,057
9	659	6,550	484	571	8,264
11	106	1,139	318	557	2,120

*:Data from IWC (1997) using the implementation simulation trials

Table 4. Wet weight composition (%) of prey species consumed by minke whales in each sub-area.

A. August

Prey species	7	8	9	11
Krill	21.1	0.0	10.3	100.0
Japanese anchovy	0.7	20.0	6.9	0.0
Pacific saury	68.3	60.0	75.5	0.0
Walleye pollock	7.7	0.0	0.0	0.0
Others	2.1	20.0	7.3	0.0

B. September

Prey species	7	8[1)]	9	11[1)]
Krill	48.0	0.0	50.0	100.0
Japanese anchovy	0.0	20.0	0.0	0.0
Pacific saury	32.9	60.0	25.0	0.0
Walleye pollock	19.1	0.0	0.0	0.0
Others	0.0	20.0	25.0	0.0

1): Using data of August

Table 5. Daily food consumption (t) of minke whales in each sub-area by using method-1.

A. August

	Krill		Japanese anchovy		Pacific saury		Walleye pollock	
Sub-area	20%	5%	20%	5%	20%	5%	20%	5%
7	50.2	73.7	2.5	3.6	184.8	258.7	27.3	39.3
8	0.0	0.0	35.8	51.5	93.2	130.5	0.0	0.0
9	96.3	141.2	96.0	138.3	725.5	1,015.7	0.0	0.0
Total	146.5	214.9	134.3	193.4	1,003.5	1,404.9	27.3	39.3

	Others		Total	
Sub-area	20%	5%	20%	5%
7	5.0	7.3	269.8	382.6
8	24.0	35.2	153.0	217.2
9	68.2	100.1	986.0	1,395.3
Total	97.2	142.6	1,408.8	1,995.1

	Krill	
Sub-area	20%	5%
11	243.9	357.6

B. September

	Krill		Japanese anchovy		Pacific saury		Walleye pollock	
Sub-area	20%	5%	20%	5%	20%	5%	20%	5%
7	114.3	167.5	0.0	0.0	89.0	124.6	67.7	97.5
8	0.0	0.0	35.8	51.5	44.9	62.9	0.0	0.0
9	467.4	685.3	0.0	0.0	349.5	489.3	0.0	0.0
Total	581.7	852.8	35.8	51.5	483.4	676.7	67.7	97.5

	Others		Total	
Sub-area	20%	5%	20%	5%
7	0.0	0.0	271.0	389.6
8	24.0	35.2	104.7	149.6
9	233.7	342.7	1,050.6	1,517.3
Total	257.7	377.9	1,426.3	2,056.4

	Krill	
Sub-area	20%	5%
11	243.9	357.6

Table 6. Daily food consumption (t) of minke whales in each sub-area by using method-2.

A. August

Sub-area	Krill	Japanese anchovy	Pacific saury	Walleye pollock
7	90.8	2.1	115.5	28.1
8	0.0	30.7	50.2	0.0
9	174.0	82.8	499.7	0.0
Total	264.8	115.6	665.4	28.1

Sub-area	Others	Total
7	5.9	242.4
8	28.1	109.0
9	80.3	836.8
Total	114.3	1,188.2

Sub-area	Krill
11	452.4

B. September

Sub-area	Krill	Japanese anchovy	Pacific saury	Walleye pollock
7	206.6	0.0	55.6	69.8
8	0.0	30.7	50.2	0.0
9	844.7	0.0	165.4	0.0
Total	1,051.3	30.7	271.2	69.8

Sub-area	Others	Total
7	0.0	332.0
8	28.1	109.0
9	274.9	1,285.0
Total	303.0	1,726.0

Sub-area	Krill
11	452.4

Table 7. Monthly food consumption ($\times 10^4$ t) of minke whales in each sub-area by using method-1.

A. August

	Krill		Japanese anchovy		Pacific saury		Walleye pollock	
Sub-area	20%	5%	20%	5%	20%	5%	20%	5%
7	0.2	0.2	0.0	0.0	0.6	0.8	0.1	0.1
8	0.0	0.0	0.1	0.2	0.3	0.4	0.0	0.0
9	0.3	0.4	0.3	0.4	2.2	3.0	0.0	0.0
Total	0.4	0.6	0.4	0.6	3.0	4.2	0.1	0.1

	Others		Total	
Sub-area	20%	5%	20%	5%
7	0.0	0.0	0.8	1.1
8	0.1	0.1	0.5	0.7
9	0.2	0.3	3.0	4.2
Total	0.3	0.4	4.2	6.0

	Krill	
Sub-area	20%	5%
11	0.7	1.1

B. September

	Krill		Japanese anchovy		Pacific saury		Walleye pollock	
Sub-area	20%	5%	20%	5%	20%	5%	20%	5%
7	0.3	0.5	0.0	0.0	0.3	0.4	0.2	0.3
8	0.0	0.0	0.1	0.2	0.1	0.2	0.0	0.0
9	1.4	2.1	0.0	0.0	1.0	1.5	0.0	0.0
Total	1.7	2.6	0.1	0.2	1.5	2.0	0.2	0.3

	Others		Total	
Sub-area	20%	5%	20%	5%
7	0.0	0.0	0.8	1.2
8	0.1	0.1	0.3	0.4
9	0.7	1.0	3.2	4.6
Total	0.8	1.1	4.3	6.2

	Krill	
Sub-area	20%	5%
11	0.7	1.1

Table 8. Monthly food consumption ($\times 10^4$ t) of minke whales in each sub-area by using method-2.

A. August

Sub-area	Krill	Japanese anchovy	Pacific saury	Walleye pollock
7	0.3	0.0	0.3	0.1
8	0.0	0.1	0.2	0.0
9	0.5	0.2	1.5	0.0
Total	0.8	0.3	2.0	0.1

Sub-area	Others	Total
7	0.0	0.7
8	0.1	0.3
9	0.2	2.5
Total	0.4	3.6

Sub-area	Krill
11	1.4

B. September

Sub-area	Krill	Japanese anchovy	Pacific saury	Walleye pollock
7	0.6	0.0	0.2	0.2
8	0.0	0.1	0.2	0.0
9	2.5	0.0	0.5	0.0
Total	3.2	0.1	0.8	0.2

Sub-area	Others	Total
7	0.0	1.0
8	0.1	0.3
9	0.8	3.9
Total	1.0	5.2

Sub-area	Krill
11	1.4

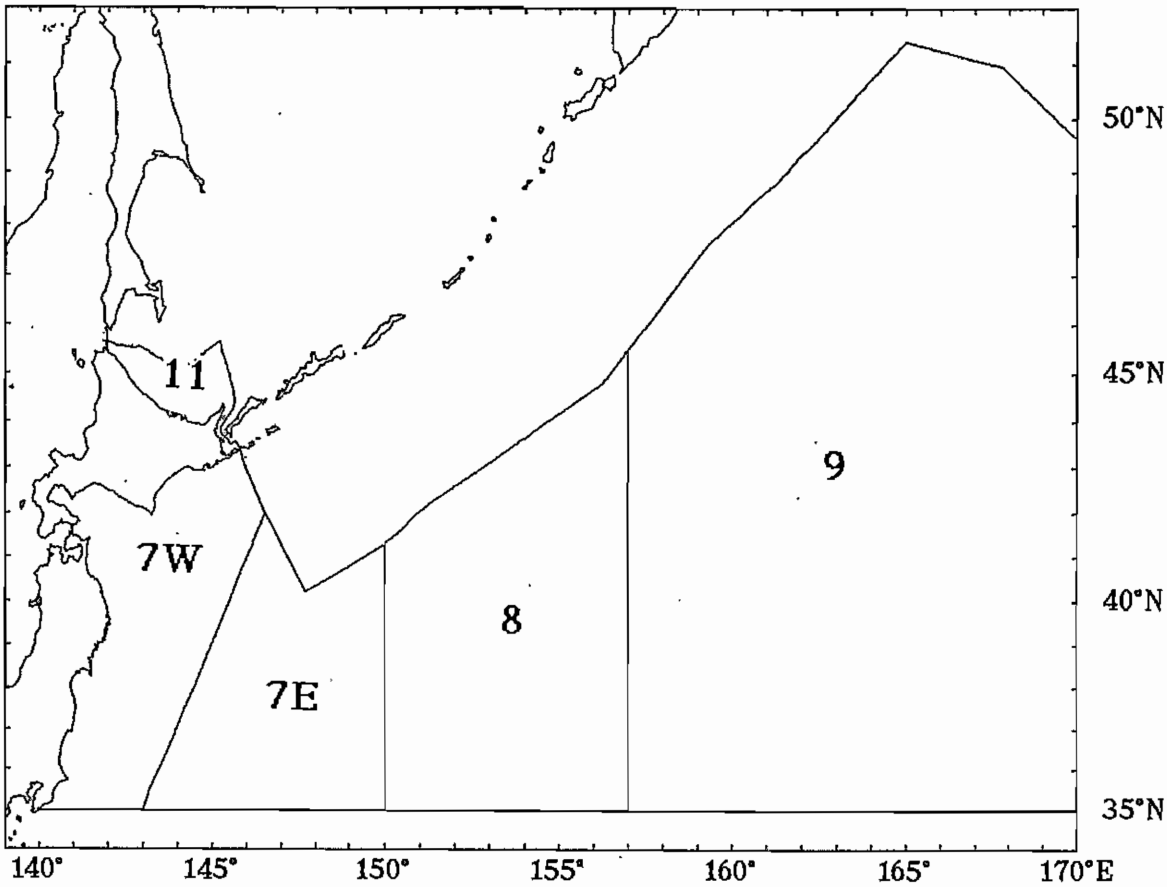

Fig.1. Sub-areas surveyed by the JARPN from 1994 to 1999. Sub-areas were based on IWC (1994), excluding the EEZ of Russia. Furthermore, sub-area 7 was divided into east (7E) and west (7W).

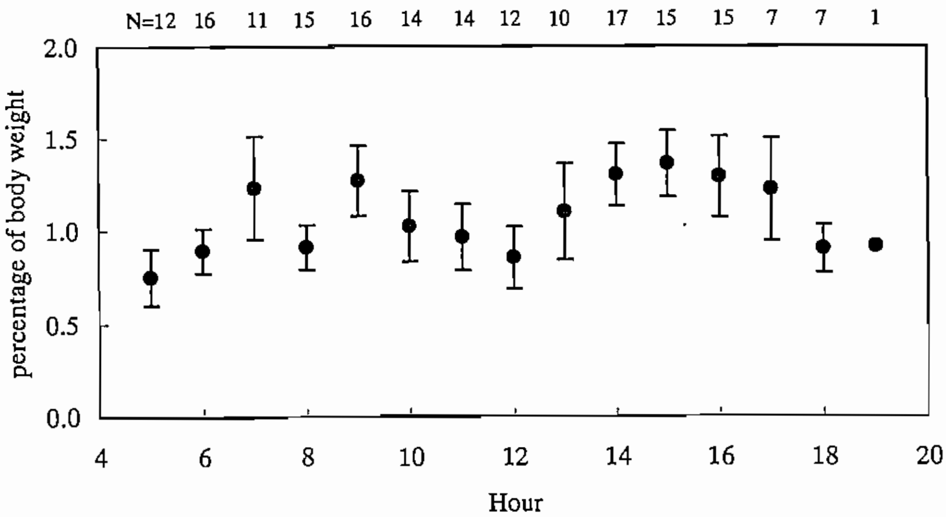

Fig.2. Diurnal change in the mean and *S.E.* of forestomach and fundus contents of Japanese anchovy as the percentage of body weight of minke whale in the Pacific side of Japan.

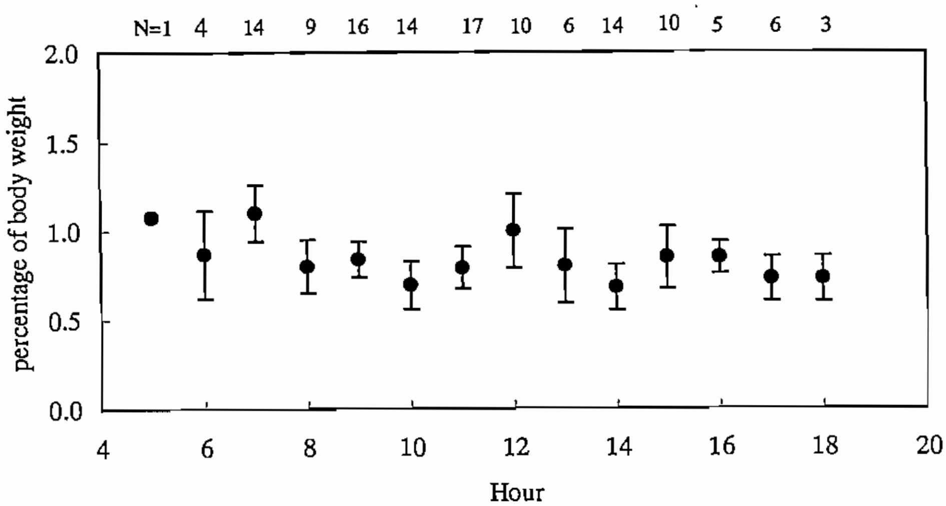

Fig.3. Diurnal change in the mean and *S.E.* of forestomach and fundus contents of Pacific saury as the percentage of body weight of minke whale in the Pacific side of Japan.

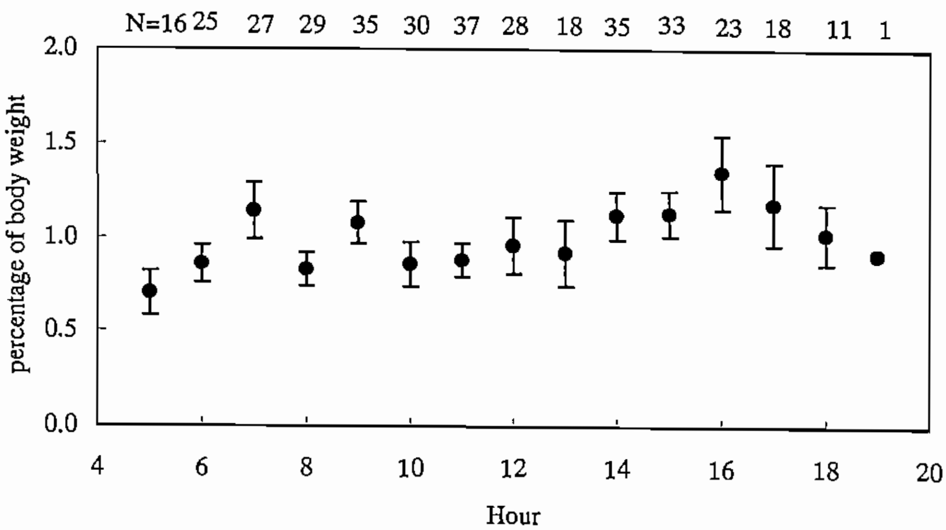

Fig.4. Diurnal change in the mean and *S.E.* of forestomach and fundus contents of total prey as the percentage body weight of minke whale in the Pacific side of Japan.

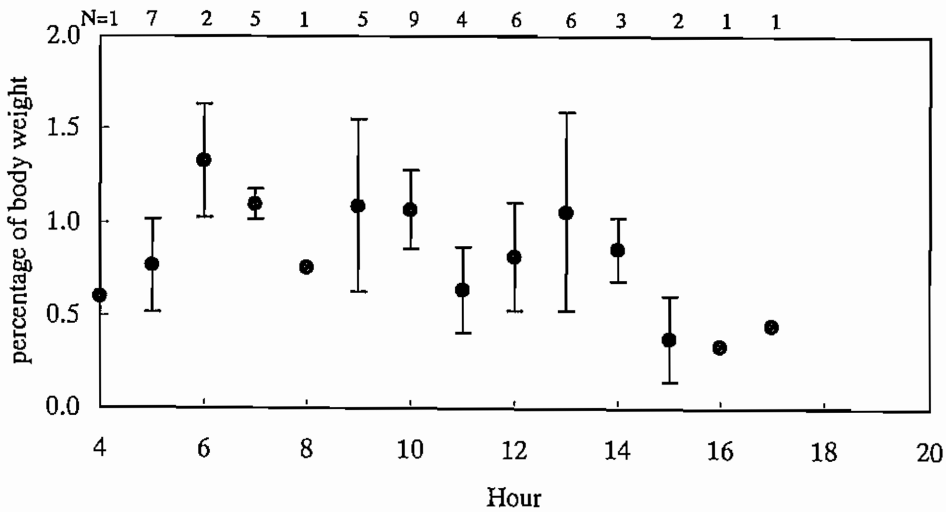

Fig.5. Diurnal change in the mean and *S.E.* of forestomach and fundus contents of krill as the percentage body weight of minke whale in the southern Okhotsk Sea.