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

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Abstract

The forestomach contents of 426 minke whales *Balaenoptera acutorostrata* sampled in the western North Pacific from May to September during 1994 – 1999 JARPN (the Japanese Whale Research Program under Special Permit in the Western North Pacific) surveys, were analyzed. Sixteen prey species consisting of 1 copepod, 4 euphausiids, 1 squid and 10 fishes, were identified. Minke whales in this region pursue single prey species aggregations. Results showed geographical and seasonal changes of prey species. In the western North Pacific (from the Japanese coast to 170°E), Japanese anchovy was the most important prey species in May and June, while Pacific saury was the most important one in July and August. Pacific saury and krill were the important prey species in September. In the southern Okhotsk Sea, krill was the most important prey species in July and August. Estimates of the daily prey consumption rate for all prey species combined were 2.6 – 5.7 % (2.6 – 3.9 % (S = 0.69), 3.9 – 5.7 % (S = 0.82)) and 1.8 – 5.2 % of body weight by two independent methods, respectively. The total prey consumption by minke whales in the western North Pacific in August and September was estimated at 85 – 122 thousand tons (S = 0.69, 0.82) and 88 thousand tons by the two methods, respectively. There included 45 – 62 thousand tons (S = 0.69, 0.82) and 28 thousand tons of Pacific saury, respectively. Total consumption of krill in southern Okhotsk Sea in August and September was 15 – 21 thousand tons (S = 0.69, 0.82) and 27 thousand tons by the two methods, respectively.

Keywords: Minke whale, prey species, prey consumption, North Pacific

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 and their prey consumption of minke whales 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 seems 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 of minke whale food habit both qualitative and quantitative. However, since 1992, there have been few published reports of their feeding habits. Furthermore, the quantitative data of stomach contents were few until now.

The Japanese Whale Research Program under Special Permit in the western North Pacific (JARPN) began in 1994 to elucidate the stock structure of western North Pacific minke whale. In 1996 a new objective related to elucidate the feeding ecology of minke whales was added and then more data on this subject were accumulated from this year.

In this study, geographical and seasonal changes of prey species were examined based on the forestomach contents of 498 minke whales collected by JARPN from spring to autumn between 1994 and 1999. The amount of food consumed by the western North Pacific minke whale is estimated using two different methods.

Material and methods

Research area and periods

The minke whales were sampled in sub-areas 7, 8, 9 and 11 excluding the EEZ of foreign countries, which were established by the IWC (IWC, 1994). Furthermore, sub-area 7 was divided into east (7E) and west (7W) (Fig. 1). Table 1 shows the months, year and number of samples in each sub-area. The JARPN surveys were conducted from May to September between 1994 and 1999. Sampled whales were immediately transported to a research base vessel, where biological measurements and sampling was carried out.

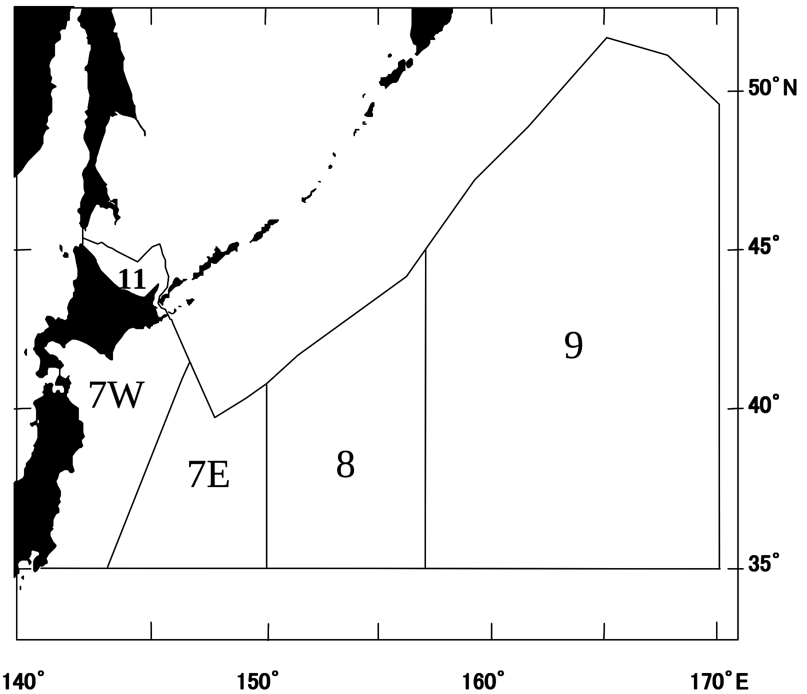


Fig. 1. Sub-areas surveyed by the JARPN from 1994-1999. Sub-areas were based on IWC (1994), excluding the EEZ of foreign countries. Furthermore, sub-area 7 was divided into east (7E) and west (7W).

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

Sampling of stomach contents

Minke whales have a four chambered stomach system (Hosokawa and Kamiya, 1971; Olsen *et al*., 1994). As soon as the whale was on the research base vessel upper deck, the four stomachs were removed within eight hours after capture. Then, each stomach contents (including liquid and excluding liquid) was weighed to the nearest 0.1 kg. The forestomach content has proved sufficient for determination of the minke whale diet in the Northeast Atlantic (Lindstrøm *et al*., 1997). The prey composition between forestomach and fundus were very similar in this study. Therefore, this study was based on contents from forestomach.

In the 1994 and 1995 JARPN surveys, a sub-sample (3-4 kg) of the 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). Then from the 1996 survey, 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.

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, in the case of 26 of the 498 minke whales sampled, the stomachs were empty. Then an analysis was based on 426 forestomach contents of minke whales.

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 or squid were found, fork length or 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 body weight of undigested 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 for each month, sub-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:

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

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:

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

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:

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

In this analysis we expressed the mean forestomach and fundus content weight as percentage of body weight (*V*i) 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 prey takes 8 hours to digested (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). Estimations were made by sex and sexual maturity stage.

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

The daily consumption of each prey species (*F*) by different maturity stages of minke whale from the field metabolic rate (*FMR*) were calculated 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 (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*)

The mean body weight of 2,400 kg and 2,500 kg for immature male and female were calculated, 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. These assumptions were adopted for estimating the feeding days.

The following assumptions were made for method-2.

C: Field metabolic rate (*FMR*)

The *FMR* according to Blix and Folkow (1995) were calculated:

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

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).

Results and discussion

Sixteen prey species consisting of 1 copepod, 4 euphausiids, 1 squid and 10 fishes, were identified (Table 2). 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.

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 2. Prey species found in stomach of minke whales sampled by the JARPN surveys

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 (Fig. 2). 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.

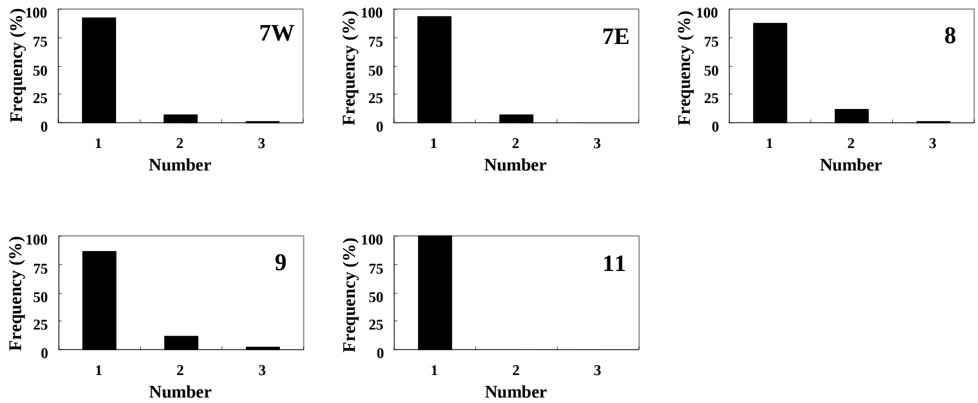


Fig. 2. Number of prey species found in the stomach of 426 minke whales sampled by JARPN surveys between 1994 and 1999, by sub-area.

In the western North Pacific, Japanese anchovy was the most important prey species in May and June, while Pacific saury was the most important one in July and August. Pacific saury and krill were the important prey species in September. In the southern Okhotsk Sea, krill was the most important prey species in July and August (Fig. 3, 4).

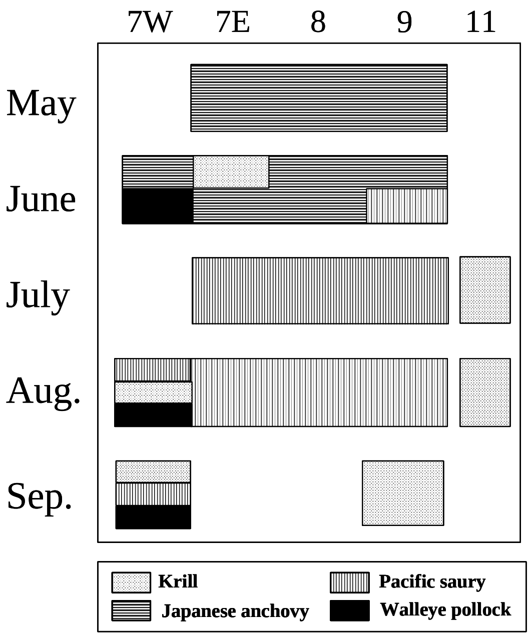


Fig. 3. Geographical and temporal changes in stomach contents of 426 minke whales sampled by JARPN surveys between 1994 and 1999 (the *CRI*).

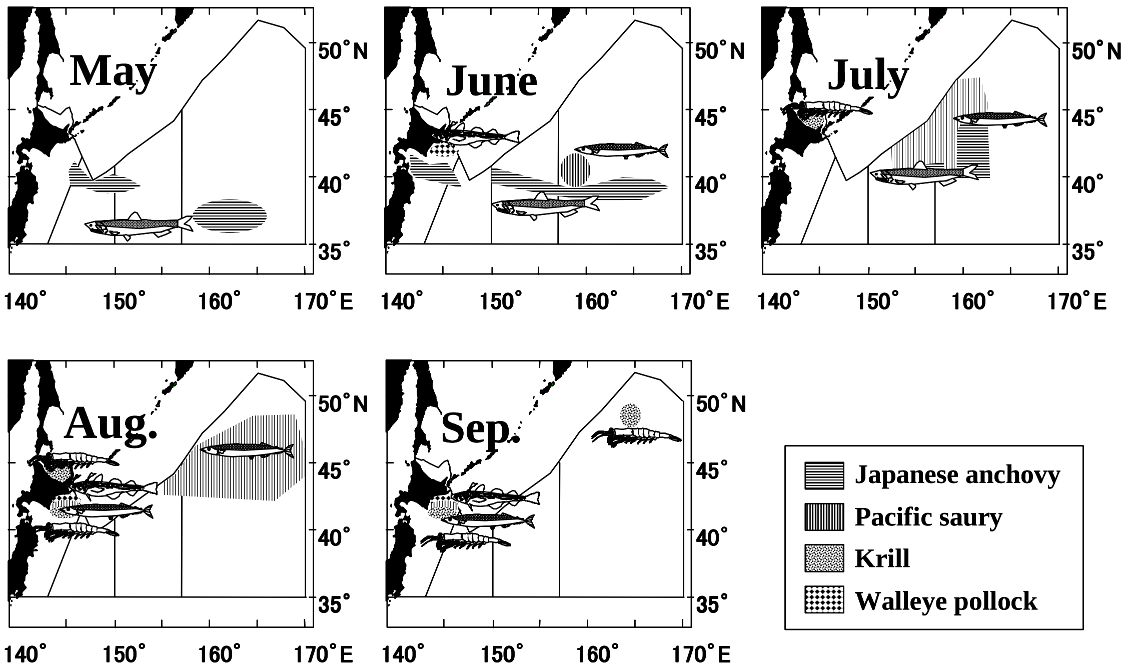
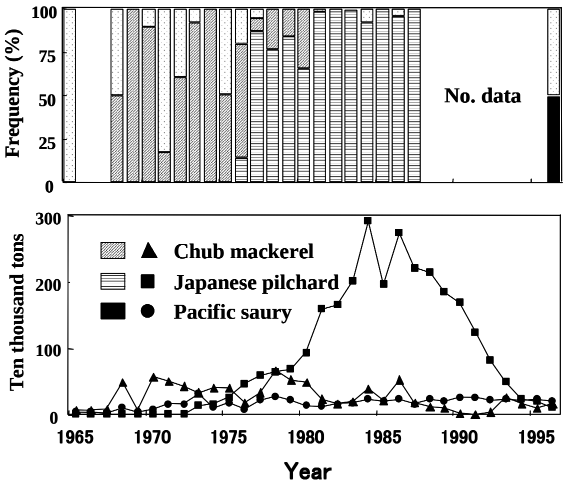


Fig. 4. Monthly distribution of minke whales sampled and its dominant prey species for the period.

Fig. 5 shows the relative frequency of occurrence of each dominant prey species consumed by minke whales in Pacific coast of Hokkaido (A)(The ministry of Agriculture, Forestry and Fisheries of Japan, 1967-1999) and the catch data of Japanese pilchard, Chub mackerel and Pacific saury in the Pacific coast of Hokkaido (B)(Kasamatsu and Tanaka, 1992). The change of prey species 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 ministry of Agriculture, Forestry and Fisheries of Japan, 1967-1999; Kasamatsu and Tanaka, 1992; this study

Fig. 5. The annual change of relative frequency of occurrence of each dominant prey species of minke whales and commercial catch in Pacific side of Hokkaido.

Estimates of the daily prey consumption rate were 2.6 – 5.7 % (2.6 – 3.9 % (S = 0.69), 3.9 – 5.7 % (S = 0.82)) and 1.8 – 5.2 % of body weight by two methods (Table 3).

Table 3. 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

The total prey consumption by minke whales in each sub-area by two methods were preliminary estimated using the abundance estimates used by the IWC to condition the implementation simulation trials (IST) of this species in the western North Pacific, the sexual maturity rates based on JARPN surveys and the wet weight composition (%) of each prey species in each sub-area in August and September (Table 4, 5).

Table 4. 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)

Table 5. The wet weight composition (%) of prey species 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

The total prey consumption by minke whales in the western North Pacific in August and September was estimated at 85 – 122 thousand tons (S = 0.69, 0.82) and 88 thousand tons by the two methods, respectively. There included 45 – 62 thousand tons (S = 0.69, 0.82) and 28 thousand tons of Pacific saury, respectively. Total consumption of krill in southern Okhotsk Sea in August and September was 15 – 21 thousand tons (S = 0.69, 0.82) and 27 thousand tons by the two methods, respectively. (Table 6).

Table 6. Estimated food consumption (thousands tons) of minke whales in each sub-area by two methods between August and September

	Krill		Japanese anchovy		Pacific saury	
Sub-area	Method-1	Method-2	Method-1	Method-2	Method-1	Method-2
Pacific side of Japan (sub area 7, 8 and 9)	22-32	39	5-7	4	45-62	28

	Walleye pollock		Others		Total	
Sub-area	Method-1	Method-2	Method-1	Method-2	Method-1	Method-2
Pacific side of Japan (sub area 7, 8 and 9)	3-4	3	11-16	13	85-122	88

	Krill	
Sub-area	Method-1	Method-2
Southern Okhotsk Sea (sub area 11)	15-21	27

Fig. 6 shows the fishing grounds of Pacific saury (during 22 July and 8 September) and the positions of minke whales sightings in sub-area 7W in the JARPN survey conducted during 24 August and 5 September 1996 (Fujise *et al.*, 1997). There is a correlation in the distribution of minke whale sighting and fishing ground of Pacific saury. 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. This observation suggests the relationship between minke whales and Pacific saury from summer to autumn in the western North Pacific.

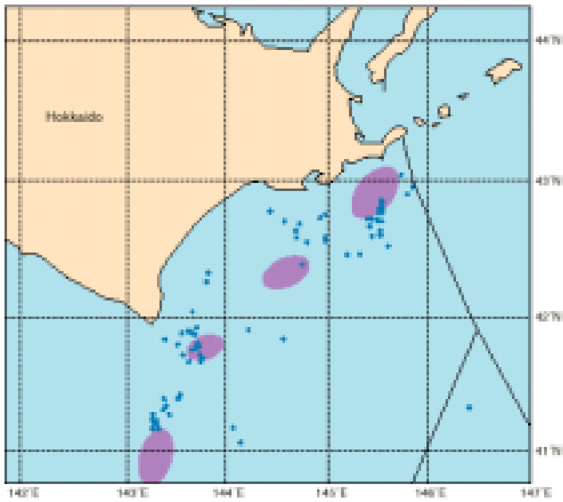


Fig. 6. Relationship between minke whale sighting and the fishing ground of Pacific saury in the Pasific side of Hokkaido (a part of sub area 7W). The information og the fishing grounds was obtained from the telex Nos. 27-33 on fishing grounds off the Pacific coast of eastern Hokkaido by the Fishing Information Service Center in Japan (Redraw from Fujise *et al.* 1997).

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, the comparative research on the distribution and abundance of important prey species such as Pacific saury, and minke whales might be necessary in the future.

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References

Arai, M. 1993. Usujiri shyuuhennkaiiki ni seisokusuru gyorui no jiseki no hikakukeitaigakuteki kenkyuu [Preliminary keys to otoliths of fishes of Usujiri and adjacent waters in Southern Hokkaido, Japan]. Graduation Thesis, Hokkaido University, 98 pp. [In Japanese].

Baker, A. de. C., Boden, B. P. and Brinton, E. 1990. A practical guide to the euphausiids of the world. *Natural History Museum Publications*: London, 96 pp.

Blix, A. S. and Folkow, L. P. 1995. Daily energy expenditure in free living minke whales. *Acta Physiol. Scand*., 153: 61-66.

Brodskii, K. A. 1950. *Calanoida of the far eastern seas and polar basin of the USSR*. Opred. Faune SSSR, 35: 1-442. [In Russian] (Transl: Israel Program for Scientific Translations, Jerusalem 1967)

Bushuev, S. G. 1986. Feeding of minke whales, *Balaenoptera acutorostrata*, in the Antarctic. *Rep. int. Whal. Commn*, 36: 241-245.

Chihara, M. and Murano, M. (eds.) 1997. *An illustrated guide to marine plankton in Japan*. Tokai Univirsity Press, Tokyo, Japan, 1574 pp.

Christensen, I. 1981. Age, determination of minke whale, *Balaenoptera acutorostrata,* from laminated structures in the tympanic bullae. *Rep. int. Whal. Commn.* 31: 245-253.

Elliott, J. M. and Persson, L. 1978. The estimation of daily rates of food consumption for fish. *J. Animal Ecol*. 47: 977-991.

Folkow, L. P. and Blix, A. S. 1993. Daily changes in surfacing rates of minke whales (*Balaenoptera acutorostrata*) in Norwegian waters. *Rep. int. Whal. Commn*, 43: 311-314.

Fujise, Y., Shimada, H., Zenitani, R., Goto, M., Matsuoka, K., Tamura, T., Lindstrøm, U., Uchida, A., Yoshida, H., Shimamoto, K., Yuzu, S., Kasai, H., Kinoshita, T., Iwata T. and Tohyama, D. 1997. Cruise report of the Japanese whale research program under a special permit in the North Pacific (JARPN) in 1996 with some preliminary analyses of data collected during the 1994-1996 JARPN surveys. International Whaling Commission SC/49/NP 8, 38 pp.

Haug, T., Gjøsæter, H., Lindstrøm, U. and Nilssen, K. T. 1995. Diets and food availability for northeast Atlantic minke whale *Balaenoptera acutorostrata* during summer 1992. *ICES Journal of Marine Science*, 52: 77-86.

Haug, T., Lindstrøm, U., K. T. Nilssen, K. T., Rottingen, I. and Skaug, H. J. 1996. Diet and food availability for Northeast Atlantic minke whales *Balaenoptera acutorostrata*. *Rep. int. Whal. Commn*, 46: 371-382.

Haug, T. Nillsen, T. Lindstrøm, U., Skaug, H. J. 1997. On the variation in size and composition of minke whale (*Balaenoptera acutorostrata*) forestomach contents. *J.Northw. Atl. Fish. Sci.* 22: 105-114.

Hosokawa, H. and Kamiya, T. 1971. Some observations on the cetacean stomachs, with special considerations on the feeding habits of whales. *Sci. Rep. Whales Res. Inst*, 23: 91-101.

Ichii, T. and Kato, H. 1991. Food and daily food consumption of southern minke whales in the Antarctic. *Polar Biology*, 11: 479-487.

International Whaling Commission. 1983. Report of the Sub-Committee on minke whales. *Rep. int. Whal. Commn*, 33: 91-122.

International Whaling Commission. 1992. Report of the Sub-Committee on North Pacific minke whale. *Rep. int. Whal. Commn*, 42: 156-177.

International Whaling Commission. 1994. Report of the Working Group on North Pacific minke whale management trials. *Rep. int. Whal. Commn*, 44: 120-144.

International Whaling Commission. 1997. Report of the working group on North Pacific minke whale trials. *Rep. int. Whal. Commn*. 47: 203-226.

Jonsgård, Å. 1982. The food of minke whale (*Balaenoptera acutorostrata*) in northern North Atlantic waters. *Rep. int. Whal. Commn*, 32: 259-262.

Kasamatsu, F and Hata, T. 1985. Notes on minke whales in the Okhotsk Sea -West Pacific area. *Rep. int. Whal. Commn*, 35: 299-304.

Kasamatsu, F. and Tanaka, S. 1992. Annual changes in prey species of minke whales taken off Japan 1948-87. *Nippon Suisan Gakkaishi*. 58: 637-651.

Kubodera, T. and Furuhashi, M. 1987. *Inaiyoubutu tyuuno ikarui oyobi hadakaiwasikagyorui no syusateinikannsuru manyuaru* [Guide to the identification of lantern fishes and cephalopods in the stomach contents]. Appendix document of the report on the modeling of ecosystem in northern North Pacific. Fisheries Agency of Japan, 65 pp. [In Japanese].

Lindstrøm, U., Haug, T. and Nilssen, K. T. 1997. Diet studies based on contents from two separate stomach content compartments of northeast Atlantic minke whales *Balaenoptera acutorostrata*. *Sarsia,* 82: 63-68.

Lockyer, C. 1981a. Growth and energy budgets of large baleen whales from the Southern Hemisphere. *FAO Fish. Ser*. (5) [Mammals in the Sea] 3: 379-487.

Markussen, N. H., Ryg, M. and Lydersen, C. 1992. Food consumption of the NE Atlantic minke whale (*Balaenoptera acutorostrata*) population estimated with a simulation model. *ICES J. mar.Sci*. 49: 317-323.

Masuda, H., Amaoka, K., Araga, C., Uyeno, T. and Yoshino, T. (eds.) 1988. *The fishes of the Japanese archipelago*. Second edition. Tokai Univirsity Press, Tokyo, Japan, 378 pp.

Miura, T. 1969. *Research methods of the productivity of limnological life*. Koudansya. Tokyo. 168-171. [in Japanese].

Morrow, J. E. 1979. Preliminary keys to otoliths of some adult fishes of the gulf of Alaska, Bering Sea, and Beaufort Sea. NOAA Technical Report NMFS circular, 420: 32 pp.

Ohe, F. 1984. Otoliths of the coastal fishes along Japanese Islands and of fishes of adjacent seas. *Reprint. Bull. The senior High School attached to Aichi University of Education*, 11: 183-220.

Ohsumi, S. 1980. Minke whales in the coastal waters of Japan, 1978. *Rep. int. Whal. Commn* 30: 307-311.

Ohsumi, S. 1982. Minke whales in the coastal waters of Japan in 1980 and a population assessment of the Okhotsk Sea - West Pacific stock. *Rep. int. Whal. Commn* 32: 283-6.

Olsen, M. A., Nordøy, E. S., Blix, A. S. and Mathiesen, S. D. 1994. Functional anatomy of the gastrointestinal system of Northeastern Atlantic minke whales (*Balaenoptera acutorostrata*). *Journal of Zoology*, London, 234: 55-74.

Omura, H. and Sakiura, H. 1956. Studies on the little piked whale from the Coast of Japan. *Sci. Rep. Whales Res. Inst*. 11: 1-37.

Pitcher, K. W. 1981. Prey of the Steller sea lion, *Eumetopias jubatus*, in the Gulf of Alaska. *Fishery Bulletin*, 79: 467-472.

Resource Council, Science and Technology Agency Japan (ed.). 1995. *Standard tables of food composition in Japan*, 4th revised edition. 544 pp. [In Japanese].

Sekiguchi, K.1994. *Studies on feeding habits and dietary analytical methods for smaller odontocete species along the Southern African coast*. Ph. D. thesis, University of Pretoria. 259 pp.

Tamura, T., Fujise, Y. and Shimazaki, K. 1998. Diet of minke whales *Balaenoptera acutorostrata* in the Northwestern part of the North Pacific in summer, 1994 and 1995. *Fisheries Science*. 64(1): 71-76.

Tamura, T. 1998. *The study of feeding ecology of minke whales in the Northwest Pacific and the Antarctic*. D. C. Thesis. Hokkaido University. 125 pp. [In Japanese].

Tobayama, T. 1974. *Studies on the feeding habits of the little toothed whales*. Ph. D. thesis, University of Tokyo. 231 pp. [In Japanese].

Tomilin, A. G. 1967. *Mammals of the USSR and Adjacent Countries. Cetacea*. 9. Israel Prog. Sci., Jerusalem, 1967: 717 pp [translation].

The minster of Agriculture, Forestry and Fisheries of Japan. 1967-1999. *Gyogyouyousyokugyou seisantoukei nenpou*. [In Japanese].

Zhongxue, L., Hanguang, X., Shulin, J. and Wenxiang, H. 1983. Studies on the minke whale from the northern Yellow Sea. *Acta. Zoologica. sinca.* 29: 86-92. [In Chinese].